The Strategic Capability Investment Plan Decision Support Analysis Model

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Abstract

Updating the SCIP equipment annex for C Status and below projects is an annual process that consumes a great deal of staff time and resources. This report documents a model that strives to bring the rigor of computer simulation, risk analysis and optimization into the SCIP process. It easily lends itself to 'What if' type analyses through varying the input funding, the likelinood of a decrease in funding, the range of a possible decrease and adjustments to project start dates.

The model, once implemented, will support a more sophisticated and rigorous approach to planning and prioritizing future strategic capital (equipment) projects and, it is foreseen, form the nucleus of three distinct but related decision support analysis models where the output from an A and B capital equipment future spending model is used as input to the SCIP decision support model described herein. Its output in turn would be used as an input to a third, future O&M decision support model to determine the impact on future O&M budgets from approving and implementing the SCIP projects.

Résumé

La mise à jour de l'Annexe du matériel de PICS pour les projets C et moins est un processus annuel qui requiert beaucoup de personnel et de ressources. Ce rapport présente un modèle qui cherche à appliquer la rigueur de la simulation par ordinateur, de l'analyse du risque et de l'optimisation au processus de PICS. Le modèle mène invariablement à une analyse par simulation en variant le financement de départ, en retenant la possibilité que le financement diminue, et en considérant la marge de cette diminution et les changements dans les dates de début des projets.

Une fois mis en place, le modèle appuiera une approche plus sophistiquée et plus rigoureuse de la planification et de l'établissement de priorités des projets stratégiques ultérieurs d'immobilisation (matériel) et si tout va comme prévu, il formera le noyau de trois modèles d'analyse d'aide à la décision, distincts mais reliés, dans lesquels les résultats provenant du modèle d'achats ultérieurs d'immobilisation et de matériel A et B serviront de points de départ au modèle d'aide à la décision de PICS décrit ci après. En retour, ces résultats serviront de points de départ à un troisième modèle d'aide à la décision en O&M servant à déterminer l'incidence des budgets ultérieurs en O&M sur l'approbation et la mise en place de projets de PICS.

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Executive summary

The Strategic Capability Investment Plan (SCIP) is a high-level plan for investing in defence capabilities over a fifteen year period [1]. Previously, capability planning and long-term capital spending were not explicitly linked. With the SCIP, the department now has the ability to identify shortfalls in capability through the defence capability matrix [2] and link them explicitly with acquisitions categorized under capability thrusts.

Updating the SCIP equipment annex for C Status and below projects (planned and proposed) is an annual process. This report documents a model that strives to bring the rigor of computer simulation, risk analysis and optimization into the SCIP process. It easily lends itself to 'What if' type analyses through varying the input funding, the likelihood of a decrease in funding, the range of a possible decrease and adjustments to project start dates. The model, once implemented, will support a more sophisticated and rigorous approach to planning and prioritizing future strategic capital (equipment) projects.

The working group results for SCIP 05 were analyzed by the model with the following lessons learned:

- A clear and defendable ranking methodology must be established from the outset. "Clear" implies that the members know the procedure to follow and understand what they are ranking. "Defendable" means that the methodology is rigorous enough to withstand careful scrutiny. Such is the case with the heuristic used in Section 2.2, with numerous documented cases of utility to the department;
- There were multiple versions of the 05 plan put forward at various times. The initial set of 94 projects was scored, and yet later versions were not. It must be clear that ranking the projects has to be the last step before running the ranking heuristic. If it isn't and additional projects are added, the ranking must be redone;
- As a result of the poor initial Planning Space funding, the SCIP Decision Support Analysis (DSA) model determined that 62% of the 79 projects that were funded, start within the first three years with a maximum of 43 starts in FY 07/08 alone;
- After the 43 starts in FY 07/08, there were no starts for the next 12 years (end of current SCIP timeline) as a result of the model trying to overcome the large negative funding delta in the later years. Starting a project means that its timeline is fixed to some extent, i.e., the timeline doesn't move but can "stretch out" to the right as funding shifts to try to make the plan affordable in any FY;
- Analysis has shown that shifting projects to the right can create problems in later years as a large funding demand can shift to where there was a much smaller demand and thereby affecting the delta considerably.

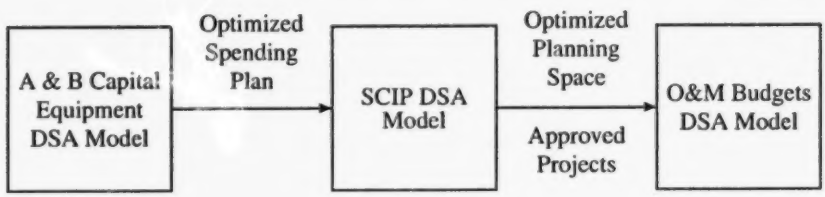
It has been proposed that a similar decision support model be developed for projecting A and B capital (equipment) project spending based on historical expenditure patterns, (e.g., level of program slippage from forecast on a project by project basis) and other risk

parameters as determined appropriate [3]. The output from this model would be a projected A and B spending plan that would then be input into the SCIP DSA Model to help determine the amount of free planning space available to start new projects.

A further O&M Sustainability (or affordability) decision support model was suggested to take the results of the SCIP DSA model, which would identify the number of new projects that could be accommodated over the planning horizon, given funding and other constraints, as an input in order to determine the impact on future O&M budgets that approving and implementing the SCIP projects would have. By applying known and projected O&M funding constraints, only those projects that respected the constraints would be candidates for approval, or the model could simply help identify future O&M funding gaps that the department would have to take action to address during the subsequent project approval process.

In effect, the SCIP planning process would involve three distinct but related decision support models with the output from the first (A and B capital project future spending model) used as an input for the second (SCIP decision support model) and the output from the second used as an input for the third (future O&M impact decision support tool) as shown in Figure ES.1 below [4].

Figure ES.1: *The Decision Support Analysis Series of Models*



P.E. Desmier; 2005; The Strategic Capability Investment Plan Decision Support Analysis Model; DRDC CORA TR 2005–31; DRDC – Centre for Operational Research and Analysis.

Sommaire

Le plan d'investissement en capacités stratégiques (PICS) est un plan de niveau supérieur d'investissement des capacités de défense pour une période de 15 ans [1]. Auparavant, la planification des capacités et les dépenses en immobilisations à long terme n'étaient pas explicitement reliées. Avec le PICS, le Ministère a maintenant la possibilité de déterminer manques de capacités à l'aide d'un tableau des capacités de défense [2] et de les relier de manière explicite aux acquisitions classifiées selon les secteurs des capacités.

La mise à jour de l'Annexe du matériel de PICS des projets C et moins (planifié et proposé) est un processus annuel. Ce rapport présente un modèle qui cherche à appliquer la rigueur de la simulation par ordinateur, de l'analyse du risque et de l'optimisation au processus de PICS. Ce modèle mène invariablement à une analyse par simulation en variant le financement de départ, en retenant la possibilité que le financement diminue, et en considérant la marge de cette diminution et les modifications dans les dates de début des projets. Une fois mis en place, le modèle appuiera une approche plus sophistiquée et plus rigoureuse de la planification et de l'établissement de priorités des projets stratégiques ultérieurs d'immobilisation (matériel). Les résultats du groupe de travail du PICS 05 ont été évalués selon le modèle et ont mené aux leçons apprises suivantes :

–Une méthodologie de classement défendable et claire doit être établie dès le départ. La "clarté" signifie que les membres doivent connaître la procédure à suivre et comprendre ce qu'ils classent. "Défendable" signifie que la méthodologie est suffisamment rigoureuse pour soutenir un examen minutieux. Tel est le cas de l'approche heuristique utilisée dans la section 2.2 et dans de nombreux cas prouvés utiles au Ministère ;
–Diverses versions du plan 05 ont été avancées à divers moments. Seuls les 94 premiers projets ont été marqués. Il doit être clair que le classement des projets est la dernière étape avant d'avoir recours au classement heuristique. Si tel n'est pas le cas ou si des projets supplémentaires sont ajoutés, le classement doit être refait ;
–À la suite d'une mauvais financement initiale de planification d'espace, le modèle de PICS de la DSA a déterminé que 62% des 79 projets qui reçoivent un financement débutent dans les trois premières années et qu'un maximum de 43 projets débuteront dans l'AF 07/08 seulement ;
–Après les 43 départs prévus dans l'AF 07/08, aucun autre départ n'est prévu pour les 12 prochaines années (fin de l'échéancier actuel de PICS) parce que le modèle a tenté de combler le large écart négatif des dernières années. Débuter un projet signifie que son échéancier est un tant soit peu fixe, c. à d. un échéancier n'est pas déplacé, mais il peut "s'étirer" vers la droite en raison des changements de financement qui rendent le plan plus abordable dans une AF particulière ;
–L'analyse a démontré que le déplacement de projets vers la droite peut créer des problèmes plus tard en raison d'une plus grande demande de financement dans un domaine généralement moins touché, affectant ainsi l'écart de manière considérable.

Jusqu'à maintenant, il a été proposé d'élaborer un modèle d'aide à la décision semblable pour les projets d'immobilisation (matériel) A et B prévus, fondés sur les structures de

dépense historiques, (p. ex., possibilité de dérapage des prévisions fondées sur le cas par cas) et les autres paramètres de risque jugés appropriés [3]. Les résultats de ce modèle représenteraient un plan d'immobilisation A et B prévus qui servirait à son tour de point de départ dans le modèle de PICS de la DSA afin de déterminer la marge de planification disponible pour commencer de nouveaux projets.

Un autre modèle d'aide à la décision sur la viabilité (ou la viabilité financière) de l'O&M est suggéré dans le but d'utiliser les résultats du modèle de PICS de la DSA afin de déterminer le nombre de nouveaux projets pouvant être entérinés dans l'horizon de planification, en fonction du financement et des autres contraintes. Le modèle servira de point de départ afin de déterminer l'incidence de l'approbation et de la mise en place des projets de PICS sur les budgets ultérieurs en O&M. En mettant en application les contraintes de financement en O&M connues et prévues, seuls les projets qui respectent ces contraintes seraient sujets à approbation, ou encore, le modèle pourrait simplement déterminer les écarts dans le financement ultérieur des O&M auquel le département aura à faire face et pour lesquels il devra prendre des mesures au cours des processus ultérieurs d'approbation de projets.

En fait, le processus de planification du PICS impliquaient trois modèles d'aide à la décision, distincts mais reliés, dont les résultats du premier (modèle de projets d'immobilisation A et B ultérieurs) servira de point de départ au second (modèle d'aide à la décision de PICS), et les résultats du second serviront de points de départ au troisième (incidence de l'outil d'aide à la décision ultérieur pour les O&M), tel que présenté à la figure ES.2 ci dessous [4].

***Figure ES.2:** Modèles d'analyse d'aide à la décision*

Modèle d'immobilisation en matériel A et B de la DSA
Plan de dépense optimisé
Modèle du PICS de la DSA
Espace de planification optimisé
Projets approuvés
Modèle de budgets en O&M de la DSA

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1 Introduction

The Strategic Capability Investment Plan (SCIP) is a high-level plan for investing in defence capabilities over a fifteen year period [1]. Previously, capability planning and long-term capital spending were not explicitly linked even though a methodology was proposed as far back as 1995 in support of the Air Force's Project Genesis [5]. With the SCIP, the department now has the ability to identify shortfalls in capability through the defence capability matrix [2] and link them explicitly with acquisitions[1] categorized under capability thrusts.

Updating the SCIP equipment annex for C Status and below (planned and proposed) projects is an annual process [6]. For SCIP 05, the steps undertaken by the SCIP 05 Working Group (WG) were as follows [7]:

1. The WG determined the level of potentially available financial planning space in FY 05/06 and beyond by determining the amount of approved (A and B) project demand, the amount to be set-aside for non-strategic projects and the appropriate level of "over-programming"[2]. Director Force Planning and Program Coordination (DFPPC) then negotiated a higher level of Capital Equipment Program over-programming for FY's 05/06 – 07/08 in order to permit greater planning flexibility in these years.

2. The WG then performed a detailed review of the existing Capital A and B projects with some projects identifying expenditure authority surpluses.

3. A series of SCIP WG meetings were convened to highlight any progress in SCIP 04 and update the list of C and below projects that make up the SCIP.

4. DFPPC, the SCIP WG Chair, directed that the WG prioritize all the projects being considered for the SCIP 05 update. This was done in a rudimentary manner having each Level 1 sponsor rank projects using three criteria and applying a ranking from 1 to 5.

5. DFPPC, then arbitrarily removed and/or re-adjusted project expenditure estimates to live within the available free planning space. This created much pushback from the WG members and resulted in expenditure amounts being re-inserted. The net result was an updated SCIP 05 that was affordable in FY 05/06 but essentially unaffordable in FY's 06/07 and 07/08.

[1] While the current plan focuses mainly on capital equipment acquisitions, there is work currently underway to include investments in Science & Technology, infrastructure and environment, human resources, concept development, experimentation and training and support.

[2] Over-programming is essentially approving expenditures (or commitments to spend against requirements) to some pre-determined level **above** the available or anticipated supply of funds. Since the department cannot normally spend more funds than it has been allocated, the level of over-programming is actively monitored throughout the fiscal year with the aim to reduce it as the fiscal year progresses. Over-programming is normally reduced through a combination of planned expenditure slippage, unforecasted expenditure slippage, and/or by instituting expenditure controls, e.g., no IT/IM procurement.

The SCIP 05 planning process began in earnest in early January 05 and ended in June 05 and consumed a great deal of staff effort and resources. A key challenge for developing the SCIP 06 Equipment Annex will be accelerating the planning process such that a plan could be ready for the Chief of Defence Staff/Deputy Minister (CDS/DM) signature prior to the start of FY 06/07.

In response to this key challenge, DMG Compt tasked DMGOR to provide decision support analysis for the development of the SCIP. The task would include incorporation of the Level 1 project prioritization criteria on the list of strategic capital equipment projects and in the development of an optimization model capturing relevant constraints, e.g., funding/overprogramming levels, that would be used to guide the project selection/prioritization decision-making process of the SCIP WG [8].

1.1 Scope

The analysis presented in this report is meant to supplant steps 4 and 5 in the SCIP WG decision making process. In Section 2, the results of the WG's "rudimentary" ranking methodology were analyzed within a heuristic called the *Slice* program that uses an enhanced version of the existing tau-x method [9]. The deficiencies in the WG's approach are explained and a proposal is made for a more rigorous and refined ranking process. In Section 3, using the solution set produced by the heuristic, a risk analysis methodology was applied to the prioritized SCIP 05 with the aim of minimizing the difference between the total project demand funding and the actual planning space generated by overprogramming the equipment allocation. This is the SCIP Decision Support Analysis (DSA) Model, an Excel based risk analysis model driven by Visual Basic macros[3]. Although too late to support SCIP 05, it is anticipated that the model would facilitate the development of SCIP 06 and, if possible, provide a useful tool for the equipment program managers to model the cash phasing of the A and B program. Section 4 provides an explanation of the SCIP DSA Model outputs with a brief discussion on the impact of developing the SCIP with the current planning space. Finally, the report concludes with recommendations on the way ahead.

[3] A user's guide to the current version (2.5) of the SCIP DSA Model, including installation, the risk analysis software, input data options and error checking are discussed in detail in Annex B.

2 Project Ranking: A New Proposal

2.1 Analysis of the Working Group's Approach

For SCIP 05, the WG ranked each project from 1 (low) to 5 (high) based on the three criteria: *Relevance to CDS Vision*, *Addresses Capability Gaps* and *Interoperability & Integration*. The ranks were then summed and the result ordered from high to low. This was their prioritization. While not optimum, the result does provide a ranking of the projects, but with only a scale of 1 to 5 to judge the merit of each project, many ties between groups of projects are to be expected.

Although the set of projects was continually changing, the WG provided 24 rankings (8 rankers[4] $\times$ 3 criteria) of 94 projects. For most ranking problems within the department, the MARCUS (Multi-Criteria Analysis and Ranking Consensus Unified Solution) program is the application of choice for the weighted m-rankings problem. MARCUS applies a complete enumeration of all possible ranking solutions [10, 11]. However, as the number of options available to be ranked grows, the total number of rankings increases as the product of an exponential and a factorial according to the formula [9]:

$$\frac{C^{n+1}n!}{2}, \tag{1}$$

where $C = \frac{1}{\ln 2} = 1.442695\ldots$ and n is the number of projects. Clearly, a MARCUS ranking of 94 projects is not practical as (1) approaches 7.1933×10^{160} possible rankings.

To accommodate large ranking problems (> 20 objects), reference [9] also describes a heuristic method where "slices", or subsets of the projects are repeatedly ranked by a branch and bound algorithm. The Slice heuristic was applied to the WG's matrix with the resulting ranking for the 94 projects (R_{94}) given as (following the notation of reference [9]):

$$\begin{aligned} R_{94} = \langle & 1\ -2\ \ 3\ -4 \ldots -16\ \ 18\ \ 20\ -21\ -22\ \ 17\ \ 19 \\ & 23 \ldots -72\ \ 73 \ldots -92\ \ 93\ -94 \rangle , \end{aligned} \tag{2}$$

where a project number written with a minus sign is tied with the project immediately preceding it. In equation 2, projects 1 and 2 are tied for first place, followed by projects 3–16 tied for second, etc.

Annex A lists the projects numbered according to the WG's ranking (Column 3 of Tables A.1–4). The Slice analysis of all 94 projects (Equation 2) and Column 4 of Tables A.1–4), aggregates the WG results into five sets of ties, the largest being a tie of 52 projects, with re-ordering of the WG rankings between projects 17–22. Many ties of projects imply that the rankers believe that the projects are equivalent in priority and that none of the tied projects should be preferred over the other. Obviously, this was not the original intention of the WG.

[4] Level 1 reps were from CAS, CLS, CMS, ADM(S&T), ADM(Pol), ADM(HR Mil), ADM(IM) and DCDS.

2.2 A Better Ranking Scheme

Rather then score each project from 1–5, the optimum methodology would be for each member of the WG to rank all 94 projects according to the three criteria; a difficult not to mention time consuming approach which would most likely lead to indifference in ranking at the lower end of the project list. Taking this into account, a somewhat less optimum but still reasonable method would be for each member to rank as many projects as possible, based on the criteria, and not rank the remainder.

To illustrate this, the WG results were sorted for each ranker and criteria and all rankings beyond the first 30 were considered a weak tie with each other, i.e., the ranker believes the projects to be equivalent and is indifferent to the relative order. The result, therefore, no longer relies on projects rising to the top based on sorting the sum of all rankings, but on more of an individual's choice based on criteria. Table 1 shows the rankings attributed to the CAS representative for the three criteria. For example, under Criteria 1, the projects (Column 1) were sorted according to the WG Score (Column 2) from high to low. The problems with the use of a simple 1–5 scoring system become apparent with inspection of Column 2. While Project 18 stands alone with a score of 5, the next 26 projects are all tied with each other with a score of 4. Similarly, the last three projects are also tied with a score of 3 . The input matrix for the Slice program is built from these results and is shown in Column 3. Here, Project 18 takes 1^{st} place, the next 26 projects are tied for 2^{nd} place and the final three projects are tied for 28^{th} place.

Table 2 lists the rankings of the top 30 projects for each criteria for the eight rankers. From a CAS perspective, Project 18, Amphibious Sealift Capability, ranked highest under Criteria 1 (Relevance to CDS Vision) whereas Project 11, Satellite Broadcast System, ranked highest under Criteria 2 (Addresses Capability Gaps), followed by Project 61, Surveillance of Space. On the other hand, both the CLS and CMS reps felt that Project 9, Medium Lift Helicopter, ranked highest under criteria 1. A total of 13 out of 24 rankings considered Project 1, Joint Information & Intel Fusion Center, to rank the highest of all projects. Interestingly, the ADM(IM) representative felt that Project 93 (TXXR to Small L1 Non-Strategic Program), second to last in the overall WG ranking, should be ranked 9^{th} under Criteria 1. Clearly this highlights the importance of representative ranking in the overall consensus approach that needs to be adopted. Although, Project 93 never made the final top 30, and it wasn't likely to given its consideration by the other rankers, it did move up from 93^{rd} place under the WG to 60^{th} under the *Top 30* approach.

Column 5 of Tables A.1–4 in Annex A lists the rankings from the Slice heuristic for the first 30 projects relative to the WG numbering scheme. Although not shown here, there were 12 groups of ties in the final results. These rankings, together with the remaining projects that make up the SCIP and listed in Annex A, should now be subjected to the SCIP DSA model. The ordering of the projects becomes critical as the heuristic will always work from the bottom (low priority) to the top (high priority)as it tries to minimize the difference between the total project funding demand and the actual funding (Planning Space) for each fiscal year.

Table 1: *CAS Project Rankings per Criteria*

	Criteria 1			Criteria 2			Criteria 3		
	Project Number	WG Score	Slice Rank	Project Number	WG Score	Slice Rank	Project Number	WG Score	Slice Rank
1	18	5	1	11	5	1	1	4	1
2	1	4	2	61	5	1	2	4	1
3	4	4	2	1	4	3	3	4	1
4	6	4	2	3	4	3	6	4	1
5	7	4	2	5	4	3	11	4	1
6	8	4	2	6	4	3	12	4	1
7	12	4	2	12	4	3	13	4	1
8	13	4	2	13	4	3	16	4	1
9	15	4	2	15	4	3	18	4	1
10	16	4	2	19	4	3	24	4	1
11	19	4	2	23	4	3	26	4	1
12	20	4	2	36	4	3	28	4	1
13	21	4	2	48	4	3	31	4	1
14	23	4	2	52	4	3	44	4	1
15	24	4	2	4	3	15	4	3	15
16	26	4	2	8	3	15	5	3	15
17	27	4	2	10	3	15	7	3	15
18	30	4	2	16	3	15	8	3	15
19	31	4	2	18	3	15	10	3	15
20	34	4	2	20	3	15	14	3	15
21	37	4	2	21	3	15	15	3	15
22	38	4	2	24	3	15	17	3	15
23	39	4	2	25	3	15	19	3	15
24	42	4	2	26	3	15	20	3	15
25	51	4	2	28	3	15	23	3	15
26	59	4	2	30	3	15	27	3	15
27	68	4	2	32	3	15	30	3	15
28	2	3	28	33	3	15	32	3	15
29	3	3	28	34	3	15	33	3	15
30	5	3	28	37	3	15	34	3	15

Table 2: *Project Rankings per Criteria*

	CAS			CLS			CMS			ADM(S&T)			ADM(Pol)			DCDS			ADM(HR Mil)			ADM(IM)		
	1[a]	2[b]	3[c]	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	18	11	1	9	1	2	9	1	2	1	1	1	6	1	1	1	1	1	2	2	1	3	5	1
2	1	61	2	18	6	1	18	7	1	4	2	2	8	2	2	2	2	2	1	20	2	7	8	3
3	4	1	3	23	7	5	29	3	3	8	3	4	9	3	3	5	8	5	4	1	4	8	9	4
4	6	3	6	1	10	6	1	4	4	9	4	8	10	4	5	9	16	7	5	3	6	9	36	5
5	7	5	11	2	13	7	2	5	6	15	6	9	14	6	7	16	17	8	6	4	19	17	49	9
6	8	6	12	3	14	9	3	8	10	17	9	15	17	7	10	17	18	10	8	5	22	46	52	17
7	12	12	13	5	15	14	4	10	12	18	13	25	18	9	11	18	22	15	9	6	76	52	53	93
8	13	13	16	7	16	15	5	12	13	20	14	27	21	11	12	22	71	16	10	7	3	53	54	2
9	15	15	18	10	21	18	6	16	18	21	16	29	23	13	14	23	3	17	11	8	5	93	60	12
10	16	19	24	11	34	19	7	18	24	22	17	31	25	14	17	61	4	18	12	9	7	1	67	14
11	19	23	26	13	2	20	8	21	26	23	18	37	36	15	26	3	5	22	13	10	8	2	73	24
12	20	36	28	15	3	23	10	22	27	25	20	43	37	16	29	4	6	33	19	11	11	4	75	26
13	21	48	31	20	4	35	16	24	28	29	22	45	42	18	31	6	7	3	20	13	13	6	76	27
14	23	52	44	21	5	3	19	25	29	30	30	49	45	23	33	7	9	4	21	15	20	10	77	29
15	24	4	4	34	8	4	20	26	38	32	31	56	47	24	38	8	10	6	23	16	21	11	79	30
16	26	8	5	37	9	8	22	27	40	41	34	3	56	26	43	11	11	9	35	19	35	12	80	32
17	27	10	7	39	11	10	24	28	44	42	36	5	63	33	48	12	12	11	42	21	41	13	81	33
18	30	16	8	41	12	11	25	29	55	45	37	6	71	38	4	14	13	12	43	22	45	14	82	35
19	31	18	10	42	18	12	26	36	64	56	49	7	1	47	15	15	14	14	46	25	9	22	83	38
20	34	20	14	46	19	13	27	38	5	57	51	10	2	48	19	19	15	19	47	32	10	23	85	41
21	37	21	15	47	20	16	28	39	8	58	54	12	3	50	24	20	19	20	48	41	12	25	86	43
22	38	24	17	54	22	17	31	40	11	74	57	13	4	55	25	21	20	21	51	48	14	27	87	46
23	39	25	19	66	23	22	33	43	14	2	58	14	5	59	27	25	21	24	53	60	17	30	88	50
24	42	26	20	77	24	24	38	44	15	3	60	16	7	64	28	29	24	25	60	76	23	32	90	55
25	51	28	23	82	25	25	39	50	16	5	84	17	11	70	34	30	25	26	76	80	24	35	93	58
26	59	30	27	4	26	26	40	55	21	6	5	18	12	5	36	32	26	27	3	12	27	41	1	59
27	68	32	30	6	27	27	42	62	22	7	7	20	13	10	40	34	27	28	7	14	28	51	2	64
28	2	33	32	8	28	28	44	64	25	10	8	22	15	12	45	35	28	29	15	23	29	66	3	65
29	3	34	33	12	30	30	47	2	31	11	10	24	16	17	47	37	29	30	22	24	30	78	4	66
30	5	37	34	14	33	32	50	6	32	12	11	26	19	21	56	41	30	32	24	26	31	5	6	73

[a]Criteria 1: Relevance to CDS Vision
[b]Criteria 2: Addresses Capability Gaps
[c]Criteria 3: Interoperability & Integration

3 The SCIP Decision Support Analysis (DSA) Model

The SCIP DSA Model is a heuristic that applies Monte Carlo simulation to iteratively minimize the difference between the total project demand funding and the actual planning space generated by overprogramming the equipment allocation. It does this by applying probability distributions to each project's demand funding from project start to project end regardless of where it lies within the SCIP timeline[5]. After a set number of iterations, a minimum difference is determined and the model outputs the calculated minimized cash phasing.

3.1 The Equipment Funding Matrix

The two main sources of data for the model are the Project Funding Matrix (PFM) and the Equipment Funding Matrix (EFM). The PFM specifies the cash phasing of each project that will be statistically adjusted by the model to fit within the equipment allocation. The EFM specifies the funding levels for significant projects, Non-Strategic (Non-Strat) funding[6], and A&B funding[7]. Table 3 shows the EFM input for the SCIP DSA Model for the first eight of the fifteen FY's of the SCIP 05/06–19/20 [13].

Rows 1–5 of Table 3 identify the cash phasing of significant projects that the department needs to program for in the future; row 6 identifies the funding for all Non-Strat projects as previously defined; rows 7 & 8 show the cash phasing for all A & B projects with A & B Reprofiling (row 7) indicating adjustments to the cash phasing. The total funding can be found in row 9 as the sum of rows 1–8. The character labelling in rows 9–14 refer to the elements in equations (3)–(5).

A user specified input is the *Equipment Allocation* in row 10. This represents the anticipated equipment funding projected for the duration of the SCIP. *Target Overprogramming* (row 11) is the percentage of "Over Planning" of funds that is greater then the funds available, however, as the SCIP is only a plan and the projects are not advanced nor approved by the Treasury Board, there is no real over-commitment at this stage [14]. Nevertheless, for planning purposes, overprogramming is assumed to allow project starts in the early FYs of the SCIP, whereas underprogramming is assumed in later FYs as shown by the negative Target Overprogramming values.

The *Planned Programming* (row 12) is just the amount that the Equipment Allocation is enhanced. If E_i represents the Equipment Allocation in FY i, then the Planned Programming (P_i^P) for the 15 FY duration of the SCIP is given by

[5]There are two timescales within the model. The first is the fiscal year timeline of the SCIP and the second is an individual project's timeline. The former will be referred as "FY" while the latter will be referred to as "year". Therefore, a project that starts in FY 3 will imply year 1 of Project X in FY 07/08.

[6]Non-Strategic projects are sponsored by a designated Level 1 advisor and approved by the Program Management Board (PMB). They will only be forwarded if they are considered of a high enough priority by the sponsoring Level 1 and there is sufficient funding available [12].

[7]A&B status projects are those that have been approved departmentally and in the case of A status, have government approved expenditure authority. The SCIP accounts for C Status and below projects only. C Status projects are "Approved in Principle" and may have authority to conduct project definition studies [12].

$$P_i^P = E_i \times [1 + O_i^T], \qquad i = 1, \ldots, 15, \tag{3}$$

where O_i^T is the Target Overprogramming in FY i.

The *Planning Space* (PS_i) is the funding ceiling available to support the project demand funding for each FY and is given by

$$\boxed{PS_i = P_i^P - T_i, \qquad i = 1, \ldots, 15,} \tag{4}$$

where T_i is the Total funding given in row 9. The Planning Space represents the main source of funding for the DSA model.

Finally, the *Real Overprogramming* (O_i^R) is illustrative of the actual over/underprogramming if no target was imposed on the Equipment Allocation. It is given by

$$O_i^R = \frac{T_i - E_i}{E_i}, \qquad i = 1, \ldots, 15. \tag{5}$$

As can be seen from row 14 of Table 3, the actual Planning Space in FYs 05/06 and 06/07 would have been negative if there were no Target Overprogramming.

3.2 The Project Funding Matrix

The second main source of input data to the model is the Project Funding Matrix (PFM). It represents the projected start and end dates of each project as well as the cash phasing. The top 30 projects in the matrix are shown in Table 4. The projects in the PFM are already ranked from high to low priority according to the Slice rankings of the WG scores. Column 2 in Table 4 allows the user to pre-select projects that will be accorded special treatment, i.e., they will only be touched as a last resort to make the plan affordable. In this case, the projects selected in Table 4 have been approved by the Joint Capability Requirement Board (JCRB)[8]. The total funding for each project (far right column in Figure 4) is also fixed, however the cash phasings are not fixed and can be adjusted by the model so as to make the overall plan affordable. It does this by applying a heuristic to the plan in order to minimize the difference between the Planning Space and the overall project funding demand in any FY.

[8]The mandate of the JCRB is to provide direction for the development of multi-purpose Canadian Forces (CF) capabilities including the Long Term Capital Plans and Future Capability Plans.

Table 3: *Equipment Funding Matrix Input to SCIP DSA Model ($000)*

		05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	...
1	New Fighter Capability	0	0	0	0	0	0	0	0	...
2	Single Class Combatant	0	0	0	60,000	125,000	150,000	500,000	1,300,000	...
3	BHS	0	1,000	30,000	150,000	400,000	400,000	19,000	0	...
4	Joint Strike Fighter Development	2,100	12,000	6,000	8,000	8,000	18,000	25,000	26,000	...
5	NATO Air Ground Surveillance	20,000	70,000	70,000	70,000	70,000	70,000	0	0	...
6	Non-Strategic Projects	47,253	131,108	217,071	242,296	269,035	294,274	312,174	317,151	...
7	A & B Reprofiling	0	0	0	353,895	773,158	300,004	0	0	...
8	A&B Projects	1,929,489	1,898,680	1,320,965	1,462,996	1,017,900	630,907	658,720	783,017	...
9	**Total,** T_i	1,998,842	2,112,788	1,644,036	2,347,187	2,663,093	1,863,185	1,514,894	2,426,168	...
10	Equipment Allocation, E_i	1,626,235	1,596,235	2,162,792	3,928,471	4,369,891	1,744,690	1,770,860	1,797,423	...
11	Target Overprogramming, O_i^T	26%	40%	25%	10%	10%	0%	-10%	-10%	...
12	Planned Programming, P_i^P	2,049,056	2,234,729	2,703,490	4,321,318	4,806,880	1,744,690	1,593,774	1,617,681	...
13	*Planning Space,* PS_i	50,214	121,941	1,059,454	1,974,131	2,143,787	-118,495	78,880	-808,487	...
14	Real Overprogramming, O_i^R	-23%	-32%	24%	40%	39%	-7%	14%	-35%	...

Table 4: *Project Funding Matrix Input to SCIP DSA Model ($000)*

Project Title		05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17	17/18	...	Total
Joint Info. & Intel Fusion Ctr.	1		3,000	5,000	20,000	20,000	6,000								...	54,000
CF Command System II				7,500	12,500	22,000	22,000	22,000	4,000						...	90,000
Wideband Satcom Capability				2,000	4,000	4,000									...	10,000
Joint Support Ship	1			82,285	96,030	194,000	209,000	276,000	305,431	394,986	266,145	82,721			...	1,906,598
Coalition Aerial Surv & Recon				1,000	4,000	4,000	2,000	5,000	5,000	1,000					...	22,000
Combat ID					1,000	10,000	14,000	14,000	14,000	14,000	4,000				...	71,000
Joint Space Support Project				3,000	15,000	2,800									...	20,800
Joint Unmanned Vehicles				10,000	70,000	150,000	250,000	165,000	75,000						...	720,000
Medium Lift Helicopter	1		8,000	100,000	400,000	400,000	92,000	25,000							...	1,025,000
Multi-mission Effects Vehicle	1	6,306	44,777	97,966	85,549	82,526	121,147	107,456	146,937	8,424					...	701,088
Satellite Broadcast System				213	7,454	10,255	9,379	18,413							...	45,714
Info. Management Interface					1,000	2,000	3,000	15,000	15,000	2,000	2,000				...	40,000
Battlefield Combat ID					1,070	1,969	3,101	5,725	23,428	59,917	61,295	28,092			...	184,597
CF Command System III									5,000	20,000	20,000	20,000	20,000	5,000	...	90,000
LF ISTAR	1	14,340	36,552	66,359	68,935	75,072	97,689	109,696	51,421	17,544	3,205				...	540,813
Polar Epsilon (EPA)				1,268	2,432	17,974	6,789	3,152							...	31,615
Red Switched Network							500	1,000	4,500	3,000	1,000				...	10,000
Amphibious Sealift Capability															...	0
NMSC	1		4,000	3,000	23,000	80,000	80,000	80,000	30,000						...	300,000
Hercules Replacement/Modern.			1,000	40,000	200,000	600,000	600,000	500,000	400,000	159,000					...	2,500,000
Urban Ops Trg Sym															...	0
Satellite Surveillance				5,000	10,000	33,000	45,000	45,000	45,000	35,000	23000				...	148,000
Medium Support Vehicle System	1	14,470	100,424	418,451	378,721	84,311	76,569								...	0
Air Omnibus Tactical Data Link X				5,000	5,000	40,000	40,000	40,000							...	40,000
Gnd Based Radar Detection Cap.				5,000	5,000	60,000	25,000	5000							...	5,000
Data Link Modernization															...	0
Military SatCom Follow On										3,000	10,000	80,000	80,000	80,000	...	253,000
HFX Class C2 Mod	1		8,416	31,963	36,747	48,748	75,008	70,931	49,949	40,741	23,701				...	185,322
Single-Ship Transition Project															...	0
Light Armoured Recce Vehicle															...	0

3.3 The Heuristic

The goal of the SCIP DSA model is to minimize the difference or variance (δ) between the Planning Space (PS_i) and the total project demand funding (F_i), where

$$F_i = \sum_{j=1}^{n} P_{ijk}, \qquad i = 1, \ldots, 15, \tag{6}$$

and P_{ijk} is the initial cash phasing for Project j in FY i and the sum is over n projects; k is a dummy index in that it only keeps track of the project year for heuristic purposes. The matrix is fully defined for any i and j.

The heuristic for minimizing $\delta_i = PS_i - F_i$ is as follows (probabilities are default values)[9]. For any i,

1. If $\delta_i \geq 0$, the Planning Space is greater then the total demand funding (6), and all projects are funded at 100% in that FY.

2. If $\delta_i < 0$, the demand funding for all projects exceeds the Planning Space and projects are allocated new funding (p_{ijk}) using a triangular distribution[10] according to the project year, as follows (all parameters are adjustable within the model):

   - Year 1: There is 0% probability of getting 100% funding for project j. New funding is $p_{ij1} = Tri(50\%, 50\%, 90\%) \times P_{ij1}$[11];
   - Year 2: There is 50% probability of getting 100% funding for project j. New funding is $p_{ij2} = Tri(60\%, 60\%, 90\%) \times P_{ij2}$;
   - Year 3: There is 65% probability of getting 100% funding for project j. New funding is $p_{ij3} = Tri(70\%, 70\%, 90\%) \times P_{ij3}$; and,
   - Year >3: There is 75% probability of getting 100% funding for project j. New funding is $p_{ijk} = Tri(80\%, 80\%, 90\%) \times P_{ijk}, \quad k > 3$.

   After each project adjustment, the model recalculates δ_i. If $\delta_i > 0$, the new funding is approved for that FY.

3. If δ_i is still less than zero, starting from the bottom of the matrix (low to high priority projects), the heuristic shifts all non pre-selected projects that are starting in that year to the right one year until δ_i is within 10% of the Planning Space, i.e., $-10\% \times PS_i \leq \delta_i \leq +10\% \times PS_i$. If this condition is satisfied, the project funding and starts are approved for that FY.

4. If after all projects are analyzed, δ_i is still not within 10% of the Planning Space, starting from the bottom of the matrix, the heuristic shifts all pre-selected projects that start in

[9] The heuristic was developed over time through discussions with Maj. R.A. Groves, DMG Compt 5.

[10] The Triangular Distribution is typically used as a subjective description of a population for which there is only limited sample data. It is based on a knowledge of the minimum and maximum and an inspired guess as to what the modal (most likely) value might be.

[11] $Tri(50\%, 50\%, 90\%)$ represents the triangular distribution with minimum value, 50%, most likely value, 50%, and maximum value, 90% of the original project demand funding

that year to the right until δ_i satisfies the 10% condition. If this condition is satisfied, the project funding and starts are approved for that FY.

5. If none of the previous steps are satisfied, the plan is not affordable for that FY.

The model uses Excel with a special add-on software called *@Risk* [15] to conduct Monte Carlo simulation by first determining randomly whether or not a project gets 100% funding. If not, using the specified triangular probability distributions, the model calculates the amount of new funding for each project until the various conditions are satisfied. The *@Risk* software allows Excel to simulate up to 1000 iterations with a minimum δ_i calculated for each FY i.

3.4 High Priority Shifting

Figures 1 and 2 show how the model has shifted high priority projects and their cash phasing to the right in order to make the plan more affordable. Figure 1 shows the top 10 projects in the worksheet prior to a model run. The colour scheme is used by the model to sum the total funding for each capability-based equipment investment thrust as described in Annex A (White: Command & Sense, Grey: Information Management/Corporate, Blue: Support & Sustain, Brown: Effective Engagement). The highlighted numbers in column 3 indicate four projects that have been pre-selected, in this case, approved by the JCRB.

The results of any shifting due to a single iteration using the default probability values are shown in Figure 2 and Table 5. Except for Project 5, all projects experience some fund shifting which occurs prior to any shift of the start date (item 2, Section 3.3). More aggressive shifting, especially in the later years of a project's life, can occur by adjusting the probability of getting 100% funding, an input to the model. The default for years > 3 is a 75% likelihood that a project will be fully funded. Care, however, must be taken in any adjustments as too high a probability may cause a trailing effect in the cash phasing whereby the funding progressively decreases with each year as $p_{ijk} = Tri(80\%, 80\%, 90\%) \times P_{ijk}$, $k > 3$ is progressively applied (item 2, Section 3.3).

Table 5: *Project and Cash Phasing Shifting of High Priority Projects*

j	Project Title	Original Start	Final Start	Funds Shift in FY(s)
1	Joint Information & Intel Fusion Center	06/07	07/08	06/07
2	CF Command System II	No Shift		09/10
3	Wideband Satcom Capability Improvement	No Shift		09/10
4	Joint Support Ship (Implementation)	No Shift		13/14
5	Coalition Aerial Surv & Recon	No Shift		No Shift
6	Combat ID	No Shift		09/10, 10/11
7	Joint Space Support Project	No Shift		09/10
8	Joint Unmanned Vehicles	No Shift		09/10, 10/11
9	Medium Lift Helicopter	06/07	07/08	06/07, 09/10
10	Multi-mission Effects Vehicle	No Shift		06/07

Proj. Starts	Title		FY05/06	FY06/07	FY07/08	FY08/09	FY09/10	FY10/11	FY11/12	FY12/13	FY13/14	FY14/15	FY15/16
	Joint Information & Intel Fusion Center (EPA)	1		3,000	5,000	20,000	20,000	6,000					
	CF Command System II				7,500	12,500	22,000	22,000	22,000	4,000			
	Wideband Satcom Capability Improvement				2,000	4,000	4,000						
	Joint Support Ship (Implementation)	1			62,265	36,030	194,000	209,000	276,000	305,431	334,366	266,145	62,721
	Coalition Aerial Surv & Recon				1,000	4,000	4,000	2,000	5,000	5,000	1,000		
	Combat ID					1,000	10,000	14,000	14,000	14,000	14,000	4,000	
	Joint Space Support Project				3,000	15,000	2,800						
	Joint Unmanned Vehicles				10,000	70,000	150,000	250,000	165,000	75,000			
	Medium Lift Helicopter (1025M)	1		6,000	100,000	400,000	400,000	92,000	25,000				
	Multi-mission Effects Vehicle	1	5,306	44,777	97,366	85,543	82,526	121,147	107,456	146,937	8,424		

Figure 1: *High Priority Shifting–Pre-DSA Model Run*

Proj. Starts	Title		FY05/06	FY06/07	FY07/08	FY08/09	FY09/10	FY10/11	FY11/12	FY12/13	FY13/14	FY14/15	FY15/16
3	Joint Information & Intel Fusion Center (EPA)	1		0	1,330	6,070	20,000	20,000	5,000	0			
3	CF Command System II				7,500	12,500	16,605	21,395	22,000	4,000	0		
3	Wideband Satcom Capability Improvement				2,000	4,000	3,065	935	0				
3	Joint Support Ship (Implementation)	1			62,265	36,030	194,000	209,000	276,000	305,431	332,176	326,955	62,721
3	Coalition Aerial Surv & Recon				1,000	4,000	4,000	2,000	5,000	5,000	1,000	0	
4	Combat ID					1,000	7,331	13,317	16,752	14,000	14,000	4,000	0
3	Joint Space Support Project				3,000	15,000	2,152	648	0				
3	Joint Unmanned Vehicles				10,000	70,000	110,174	251,646	203,180	75,000	0		
3	Medium Lift Helicopter (1025M)	1		0	4,526	103,472	400,000	333,926	158,074	25000	0		
1	Multi-mission Effects Vehicle	1	5,306	30,634	112,109	85,543	82,526	121,147	107,456	146,937	8,424	0	

Figure 2: *High Priority Shifting–Post-DSA Model Run*

Proj. Starts	Title		FY05/06	FY06/07	FY07/08	FY08/09	FY09/10	FY10/11	FY11/12	FY12/13	FY13/14	FY14/15	FY15/16
	Joint Information & Intel Fusion Center (EPA)	1		3,000	5,000	20,000	20,000	6,000					
	CF Command System II				7,500	12,500	22,000	22,000	22,000	4,000			
	Wideband Satcom Capability Improvement				2,000	4,000	4,000						
	Joint Support Ship (Implementation)	1			62,265	96,030	194,000	209,000	276,000	305,431	334,366	266,145	62,721
	Coalition Aerial Surv & Recon				1,000	4,000	4,000	2,000	5,000	5,000	1,000		
	Combat ID					1,000	10,000	14,000	14,000	14,000	14,000	4,000	
	Joint Space Support Project				3,000	15,000	2,800						
	Joint Unmanned Vehicles				10,000	70,000	150,000	250,000	165,000	75,000			
	Medium Lift Helicopter (102SM)	1		6,000	100,000	400,000	400,000	92,000	25,000				
	Multi-mission Effects Vehicle	1	6,306	44,777	97,366	85,543	82,526	121,147	107,456	146,937	8,424		

Figure 1: *High Priority Shifting–Pre-DSA Model Run*

Proj. Starts	Title		FY05/06	FY06/07	FY07/08	FY08/09	FY09/10	FY10/11	FY11/12	FY12/13	FY13/14	FY14/15	FY15/16
3	Joint Information & Intel Fusion Center (EPA)	1		0	1,930	6,070	20,000	20,000	6,000	0			
3	CF Command System II				7,500	12,500	16,605	27,395	22,000	4,000	0		
3	Wideband Satcom Capability Improvement				2,000	4,000	3,065	935	0				
3	**Joint Support Ship (Implementation)**	1			62,265	96,030	194,000	209,000	276,000	305,431	332,176	328,355	62,721
3	Coalition Aerial Surv & Recon				1,000	4,000	4,000	2,000	5,000	5,000	1,000	0	
4	**Combat ID**					1,000	7,331	13,917	16,752	14,000	14,000	4,000	0
3	Joint Space Support Project				3,000	15,000	2,152	648	0				
3	Joint Unmanned Vehicles				10,000	70,000	110,174	251,646	203,180	75,000	0		
3	**Medium Lift Helicopter (102SM)**	1		0	4,528	103,472	400,000	333,926	158,074	25000	0		
1	Multi-mission Effects Vehicle	1	6,306	30,634	112,103	85,543	82,526	121,147	107,456	146,937	8,424	0	

Figure 2: *High Priority Shifting–Post-DSA Model Run*

To better understand the shifting of funds and start dates in the model, it is necessary to have an understanding of the funding δ and the hurdles that must be overcome in order to make the plan affordable. Table 6 shows the main funding specified for SCIP 05 for each FY. Column 2 lists the sum of project demand funding; column 3 lists the total Planning Space from row 13 of Table 3; and, column 3 lists the difference, column 3 – column 2.

According to item 1, Section 3.3, a positive δ in any FY would mean 100% funding for all projects in that FY[12]. Consequently, Project 10, Multi-mission Effects Vehicle, will have its start date locked although its cash phasing can slip to the right as it has done in FY 06/07 (Figure 2). Also, the relatively small delta's in FY's 05/06 – 09/10 mean that, with shifting of funds and start dates, the program can be made affordable. Unfortunately, the impact of too much Planning Space funds is that far too many projects will be able to start within the first 4-5 FYs (note the "Proj. Starts" column in Figure 2 which has all 10 projects starting in the first four FYs) which will impact later starts as the large negative deltas experienced in FY's > 09/10 will be very difficult to overcome without the infusion of additional funding or the cancellation of expensive projects.

Table 6: *Original Project Funding Demand, Planning Space and Delta*

Fiscal Year, i	Project Funding (F_i) ($000)	Planning Space (PS_i) ($000)	Funding Delta (δ_i) ($000)
05/06	30,329	50,214	19,885
06/07	276,492	121,941	-154,551
07/08	1,066,632	1,059,454	-7,178
08/09	2,189,918	1,974,131	-215,787
09/10	2,811,859	2,143,787	-668,072
10/11	2,487,483	-118,495	-2,605,978
11/12	2,533,231	78,880	-2,454,351
12/13	2,188,813	-808,487	-2,997,300
13/14	1,932,393	-634,602	-2,566,995
14/15	1,586,152	-855,498	-2,441,650
15/16	1,117,569	-72,209	-1,189,778
16/17	677,119	298,448	-378,671
17/18	362,573	-205,374	-567,947
18/19	315,250	-881,455	-1,196,705
19/20	272,706	-1,005,277	-1,277,983
Future FYs	972,608	0	-972,608
Totals	20,821,127	1,145,459	-19,675,668

[12] Once a project starts (year=1) regardless of the FY, its start date cannot be shifted although its cash phasing can still be adjusted.

3.5 Low Priority Shifting

Figures 3 and 4 show how the model has shifted low priority projects and their cash phasing to the right in order to make the plan more affordable[13]. Figure 3 shows the bottom 10 projects in the worksheet prior to a model run. The colour scheme is the same as per Figures 1 and 2. As per the heuristic (items 2–4, Section 3.3), Figure 4 and Table 7 show that the greatest impact in project starts and cash phasing will occur towards the bottom of the list. These are the low priority projects and start dates can be shifted significantly (Projects 89 and 92). Funds shifting to the right can also be significant (Projects 89, 92, 95 and 96) as the model seeks to minimize the delta which it finds difficult to do given the large negative delta it needs to overcome (Table 6). Interestingly, the pre-approved projects (90, 95 and 96) are not shifted due to their early start dates and only 95 and 96 experience some significant funds shift.

Table 7: *Project and Cash Phasing Shifting of Low Priority Projects*

j	Project Title	Original Start	Final Start	Funds Shift in FY(s)
89	MK 46 Torpedo Replacement	13/14	16/17	13/14 – 16/17
90	CEMS Multitool	No Shift		No Shift
91	CIMP	Not Funded		Not Funded
92	MK 48 Torpedo Refurbishment	09/10	16/17	09/10 – 16/17
93	TXXR to Small L1 Non-Strategic Program	06/07	07/08	06/07
94	Snowbird Aircraft Replacement Project	Not Funded		Not Funded
95	AURORA ASLEP	No Shift		09/10, 13/14 – 16/17
96	IM Corporate Requirements	No Shift		12/13 – 16/17
97	NBCD Company Enhancements	No Shift		No Shift
98	DART Upgrades	No Shift		No Shift

[13] After the WG completed their ranking of the 94 projects, four additional projects (#'s 95–98) were added to the list. However, since they were never ranked, they automatically drop to the end of the list.

Proj. Starts	Title		FY05/06	FY06/07	FY07/08	FY08/09	FY09/10	FY10/11	FY11/12	FY12/13	FY13/14	FY14/15	FY15/16	FY16/17
	MK 46 Torpedo Replace										10,000	10,000	50,000	50,000
	CEMS Multitool	1			1,170									
	CIMP													
	MK 46 Torpedo Refurbish						2,000	8,000	20,000	20,000	20,000	20,000	20,000	20,000
	TXXR to Small L1 Non-strategic program			5,424										
	Snowbird Aircraft Replacement Project													
	AURORA ASLEP	1	1,050	24,300	39,265	78,676	74,351	75,116	76,303	77,501	11,196	1,607		
	IM Corporate Requirements	1	5,775	55,206	62,736	78,273	86,424	66,522	111,548	124,935	126,612	103,728	18,519	
	NBCD Company Enhancements				16,013	14,660								
	DART Upgrades					1,500	7,000	7,000	1,000					

Figure 3: *Low Priority Shifting–Pre-DSA Model Run*

Proj. Starts	Title		FY05/06	FY06/07	FY07/08	FY08/09	FY09/10	FY10/11	FY11/12	FY12/13	FY13/14	FY14/15	FY15/16	FY16/17
12	MK 46 Torpedo Replace										0	0	0	2,437
3	CEMS Multitool	1			1,170									
	CIMP													
12	MK 46 Torpedo Refurbish						0	0	0	0	0	0	0	81
3	TXXR to Small L1 Non-strategic program			0	2,561	2,463								
	Snowbird Aircraft Replacement Project													
1	AURORA ASLEP	1	1,050	24,300	39,265	78,676	64,090	65,417	76,303	77,501	9,566	2,713	459	68
1	IM Corporate Requirements	1	5,775	55,206	62,736	78,273	86,424	66,522	111,548	106,067	120,348	131,120	15,141	3,178
3	NBCD Company Enhancements				16,013	14,660								
4	DART Upgrades					1,500	7,000	7,000	1,000	0				

Figure 4: *Low Priority Shifting–Post-DSA Model Run*

Proj. Starts	Title		FY05/06	FY06/07	FY07/08	FY08/09	FY09/10	FY10/11	FY11/12	FY12/13	FY13/14	FY14/15	FY15/16	FY16/17
	MK 46 Torpedo Replace										10,000	10,000	50,000	10,000
	CEMS Multitool	1			1,170									
	CIMP													
	MK 48 Torpedo Refurbish						2,000	6,000	20,000	20,000	20,000	20,000	20,000	20,000
	TXXR to Small L1 Non-strategic program			5,424										
	Snowbird Aircraft Replacement Project													
	AURORA ASLEP	1	1,050	24,300	39,265	78,876	74,351	75,116	76,303	77,501	11,198	1,607		
	IM Corporate Requirements	1	5,775	55,206	62,736	78,273	86,424	66,522	111,548	124,335	126,812	103,728	16,119	
	NBCD Company Enhancements				18,013	14,660								
	DART Upgrades					1,500	7,000	7,000	1,000					

Figure 3: *Low Priority Shifting–Pre-DSA Model Run*

Proj. Starts	Title		FY05/06	FY06/07	FY07/08	FY08/09	FY09/10	FY10/11	FY11/12	FY12/13	FY13/14	FY14/15	FY15/16	FY16/17
12	MK 46 Torpedo Replace										0	0	0	2,437
3	CEMS Multitool	1			1,170									
	CIMP													
12	MK 48 Torpedo Refurbish						0	0	0	0	0	0	0	81
3	TXXR to Small L1 Non-strategic program			0	2,961	2,463								
	Snowbird Aircraft Replacement Project													
1	AURORA ASLEP	1	1,050	24,300	39,265	78,876	64,050	85,417	76,303	77,501	9,566	2,713	456	68
1	IM Corporate Requirements	1	5,775	55,206	62,736	78,273	86,424	66,522	111,548	126,067	120,348	131,120	15,141	3,378
3	NBCD Company Enhancements				18,013	14,660								
4	DART Upgrades					1,500	7,000	7,000	1,000	0				

Figure 4: *Low Priority Shifting–Post-DSA Model Run*

4 SCIP DSA Model Output

The @Risk software allows Excel to simulate SCIP cash phasing adjustments to minimize the difference between project demand funding and the planning space (delta) for 1000 iterations. The instructions for setting up and running the application are covered in Annex B. For each iteration, the simulation generates outputs for the delta, percent the delta is of the planning space, the number of projects approved in any fiscal year, the funding per investment thrust and the cash phasing per project.

4.1 Heuristic Optimization

A solution is presented for the minimum delta for each FY after adjustments to each project's cash phasing; however, because the minimum presented is based on random sampling of probability distributions, there will be a different solution provided for each FY and each iteration. Sorting the output deltas allows the user to determine heuristically, the "optimum" solution if we assume that this solution will consist of the minimum difference above and below the line defined by $\delta = 0$. Therefore, the driver for all output is based on finding the minimum positive sum ($\mathcal{S}_n$) for k iterations, aggregated in periods of 4, 5, 6, ..., 10 and 15 FY's as in

$$\mathcal{S}_n = Min\left[\left(\sum_{i=1}^{n}|\delta_i|\right)^1, \left(\sum_{i=1}^{n}|\delta_i|\right)^2, \ldots, \left(\sum_{i=1}^{n}|\delta_i|\right)^k\right], n = 4, \ldots, 10, 15, \quad (7)$$

where $|\delta_i|$ denotes the absolute value of δ_i values for each of k iterations. The absolute value is taken such that poor solutions consisting of large positive and negative deltas in any one iteration would not cancel each other out and thereby provide a minimum contribution to equation (7).

Equation (7) is used to sort all output according to periods of time, whereby users interested in Horizon 1, 2 or 3 optimization can easily extract the relevant results. For example, if a user was interested in the cash phasing that provided the best solution for the next 10 years, they would only be concerned with an $n = 10$ solution of equation (7).

For example, Table 8 shows the solution for the first 10 results for FYs 05/06–09/10 ranked from best to worse based on taking the absolute value of δ_i. If the model were ranking solely based on the sum of deltas in the first five years, Solution 7 would rank in first place and Solution 1 would drop to second place followed by solution 9 in third place.

Table 8: *Optimized Solution for δ_i for the First Five FYs ($000); negative values are in parentheses*

Solution	05/06	06/07	07/08	08/09	09/10
1	19885	(2557)	452599	764835	(40701)
2	19885	(24932)	480943	793561	(1332)
3	19885	(26907)	483670	790336	(11392)
4	19885	(20553)	481495	797171	14257
5	19885	(1095)	457661	813738	42432
6	19885	(23948)	480622	806662	4518
7	19885	(7181)	464699	784299	(71627)
8	19885	(7338)	452355	836568	(32974)
9	19885	(20926)	479193	781398	(48280)
10	19885	(14293)	468413	836911	(11238)

4.2 The Report Sheet

Figure 5 shows a portion of the main output worksheet from which all results can be accessed. This was for a run of 1000 iterations with all defaults values accepted. As noted at the top-left, the run took 00:15:27 (hrs:mins:secs) to complete. Also at the top-left, a 'Print Report' icon allows the user to print the entire report (8 pages of output) to the default printer.

Just below the print icon there is the first of eight tables that describe the optimized output from the run. Shown are the results from equation (7) with $n = 4$. The first column lists the percentage the initial WG delta is of the Planning Space (labelled 'ceiling'). The second column lists the initial delta for each FY (column 3). The next three columns list the simulation results per FY. They are the percentage of the Planning Space, the delta, and the number of approved projects.

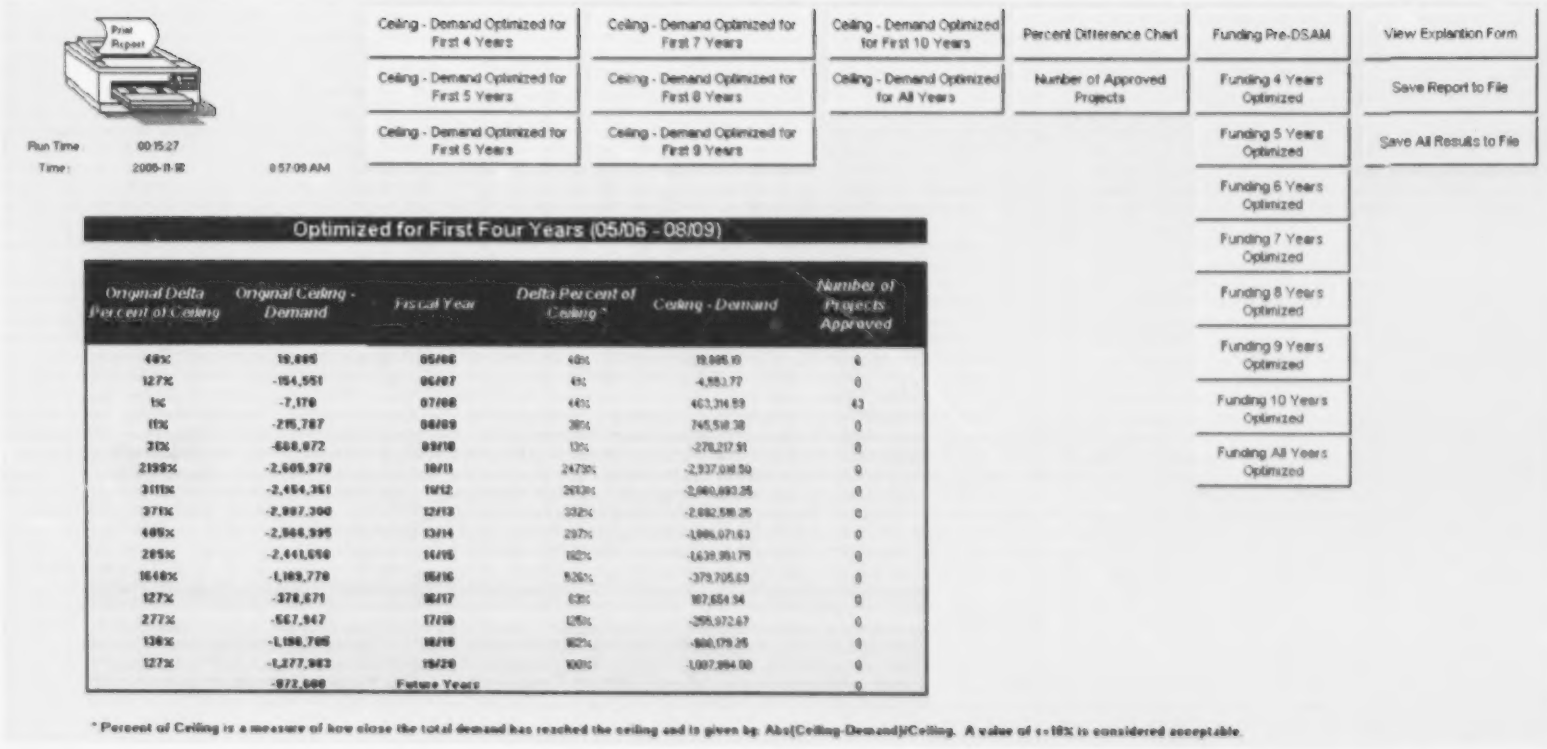
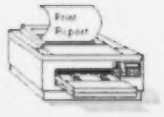

Print Report
Run Time: 00:15:27
Time: 2005-11-02 8:57:09 AM
Ceiling - Demand Optimized for First 4 Years
Ceiling - Demand Optimized for First 5 Years
Ceiling - Demand Optimized for First 6 Years
Ceiling - Demand Optimized for First 7 Years
Ceiling - Demand Optimized for First 8 Years
Ceiling - Demand Optimized for First 9 Years
Ceiling - Demand Optimized for First 10 Years
Ceiling - Demand Optimized for All Years
Percent Difference Chart
Number of Approved Projects
Funding Pre-DSAM
Funding 4 Years Optimized
Funding 5 Years Optimized
Funding 6 Years Optimized
Funding 7 Years Optimized
Funding 8 Years Optimized
Funding 9 Years Optimized
Funding 10 Years Optimized
Funding All Years Optimized
View Explantion Form
Save Report to File
Save All Results to File
Optimized for First Four Years (05/06 - 08/09)
Orignal Delta Percent of Ceiling
Orignal Ceiling - Demand
Fiscal Year
Delta Percent of Ceiling *
Ceiling - Demand
Number of Projects Approved
40% 19,895 05/06 40% 19,895.10 6
127% -154,551 06/07 4% -4,553.77 0
1% -7,170 07/08 44% 463,314.59 43
11% -215,787 08/09 38% 745,510.38 0
31% -668,072 09/10 13% -270,217.91 0
2199% -2,605,970 10/11 2473% -2,937,018.50 0
3111% -2,454,351 11/12 2653% -2,960,693.25 0
371% -2,997,300 12/13 332% -2,882,588.25 0
469% -2,966,995 13/14 297% -1,986,071.63 0
285% -2,441,650 14/15 182% -1,639,351.79 0
1648% -1,189,770 15/16 926% -379,705.63 0
127% -378,671 16/17 63% 107,654.94 0
277% -567,947 17/18 126% -255,972.67 0
136% -1,198,705 18/19 82% -660,179.25 0
127% -1,277,983 19/20 100% -1,007,994.00 0
-972,600 Future Years 0
* Percent of Ceiling is a measure of how close the total demand has reached the ceiling and is given by: Abs(Ceiling-Demand)/Ceiling. A value of <=18% is considered acceptable.

Figure 5: The Report Sheet



Run Time 00:15:27
Time: 2005-11-18 6:57:09 AM

Ceiling - Demand Optimized for First 4 Years
Ceiling - Demand Optimized for First 5 Years
Ceiling - Demand Optimized for First 6 Years
Ceiling - Demand Optimized for First 7 Years
Ceiling - Demand Optimized for First 8 Years
Ceiling - Demand Optimized for First 9 Years
Ceiling - Demand Optimized for First 10 Years
Ceiling - Demand Optimized for All Years
Percent Difference Chart
Number of Approved Projects
Funding Pre-DSAM
Funding 4 Years Optimized
Funding 5 Years Optimized
Funding 6 Years Optimized
Funding 7 Years Optimized
Funding 8 Years Optimized
Funding 9 Years Optimized
Funding 10 Years Optimized
Funding All Years Optimized
View Explanation Form
Save Report to File
Save All Results to File

Optimized for First Four Years (05/06 - 08/09)

Original Delta Percent of Ceiling	Original Ceiling - Demand	Fiscal Year	Delta Percent of Ceiling *	Ceiling - Demand	Number of Projects Approved
40%	19,895	05/06	40%	19,895.10	6
127%	-154,551	06/07	4%	-4,551.77	0
1%	-7,178	07/08	44%	463,314.53	43
11%	-215,787	08/09	28%	745,518.18	0
31%	-668,072	09/10	13%	-276,217.91	0
2199%	-2,605,978	10/11	247%	-2,937,018.50	0
3111%	-2,454,351	11/12	263%	-2,060,693.25	0
371%	-2,997,300	12/13	232%	-2,882,515.25	0
405%	-2,566,995	13/14	297%	-1,886,071.63	0
285%	-2,441,650	14/15	152%	-1,633,951.75	0
1648%	-1,189,770	15/16	526%	-379,705.63	0
127%	-378,671	16/17	63%	187,654.94	0
277%	-567,947	17/18	126%	-255,972.67	0
136%	-1,196,705	18/19	102%	-900,179.25	0
127%	-1,277,983	19/20	100%	-1,007,954.09	0
	-972,608	Future Years			0

* Percent of Ceiling is a measure of how close the total demand has reached the ceiling and is given by: Abs(Ceiling Demand)/Ceiling. A value of <= 10% is considered acceptable.

Figure 5: The Report Sheet

4.3 The Graphical Output

To the right of the icon there are 22 buttons that allow the user to navigate the various graphical outputs or save the results to files. The eight buttons labelled 'Ceiling – Demand Optimized for ...' provide the graphical solutions to equation (7). Figure 6 illustrates the output for a 'first four years' optimization. With no changes to the defaults, the results show improvement over the original delta. A large positive delta at FY 08/09 is not due to the heuristic trying to minimize the delta, instead it is a function of the shifting of funds to the right, i.e., in some cases, large demands in FY 08/09 have been shifted into later years in order to make earlier years more affordable. The result being a smaller overall project demand for a fairly substantial Planning Space dollar value in FY 08/09 ($1,974,131,000 in Table 6) . In later years, only through an strong infusion of funding could the SCIP hope to overcome the large negative delta.

Using the buttons on the chart, the result can either be printed or saved to a file[14]. Clicking the button 'View Report Sheet' will navigate the user back to the Report.

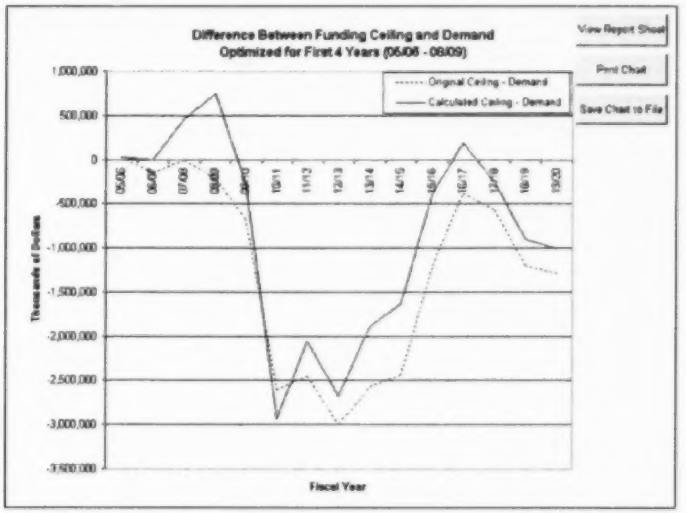


Figure 6: *Optimized Delta for First Four Years*

[14]The 'Save All Results to File' button on the Report sheet is particularly useful if a user wished to visualize the changes afforded through each optimization option. Since each result is placed on a separate Excel sheet, any changes can be quickly visualized by moving from sheet to sheet.

The next two buttons on the Report Sheet are 'Percent Difference Chart' and 'Number of Approved Projects'. Clicking the former would bring up the chart in Figure 7. This chart shows what percentage the delta is of the Planning Space optimized for the even years. Ideally, a solution is found when the delta is within 10% of the Planning Space. Unfortunately, under the present constraints, that is very difficult to do. Except for the FY 10/11 value, all results are better then the original delta which gives support to the heuristic.

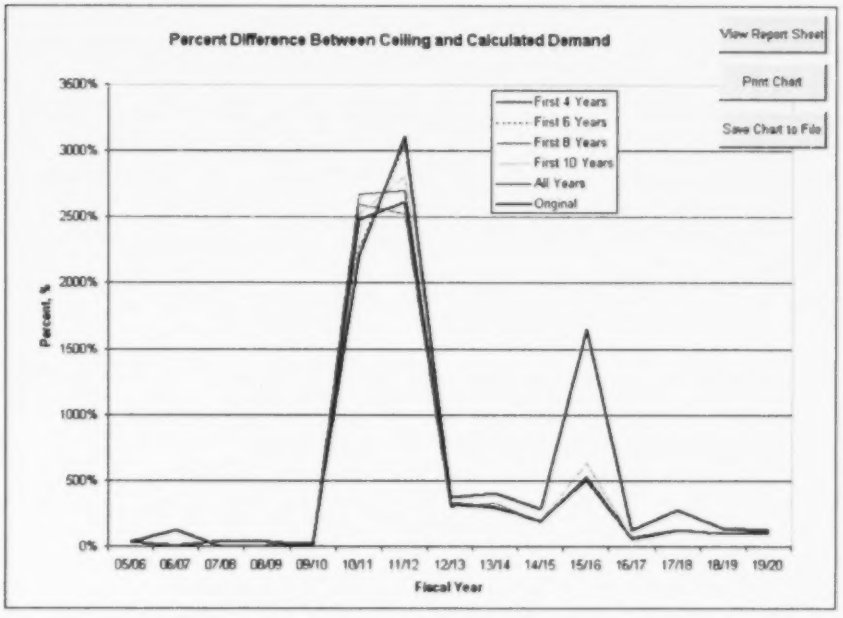


Figure 7: *Delta Percentage of the Planning Space*

A consequence of poor initial Planning Space conditions for running the model is highlighted in Figure 8. As Table 6 and Figure 9 show, a large influx of cash in the early years allows 49 project starts in the first three years alone. The demand for cash in the later years from these 49 as well as the negative Planning Space funding mean that no other projects can start; in fact, with 19 projects not funded at all, the remaining 30 are continually shifted to the right as the model tries in vain to minimize the delta.

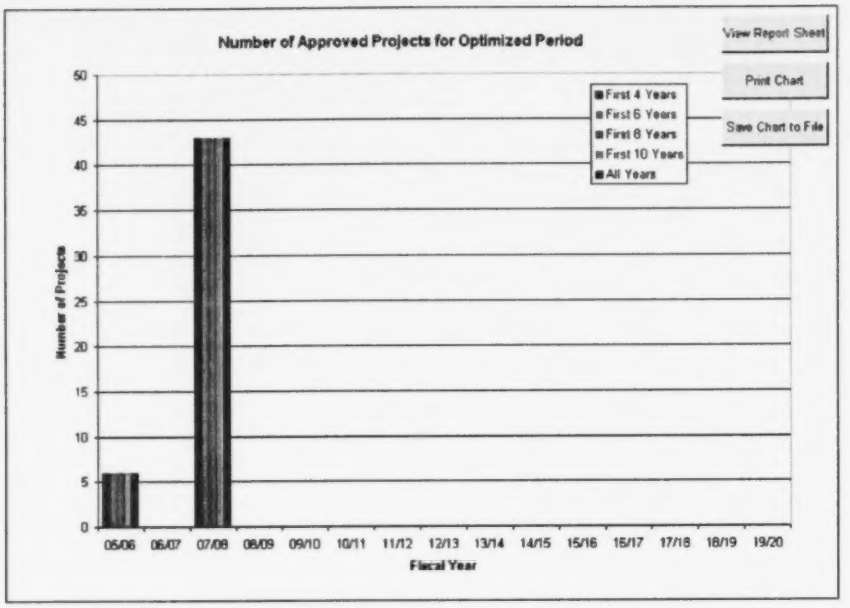


Figure 8: *The Number of Projects Starts*

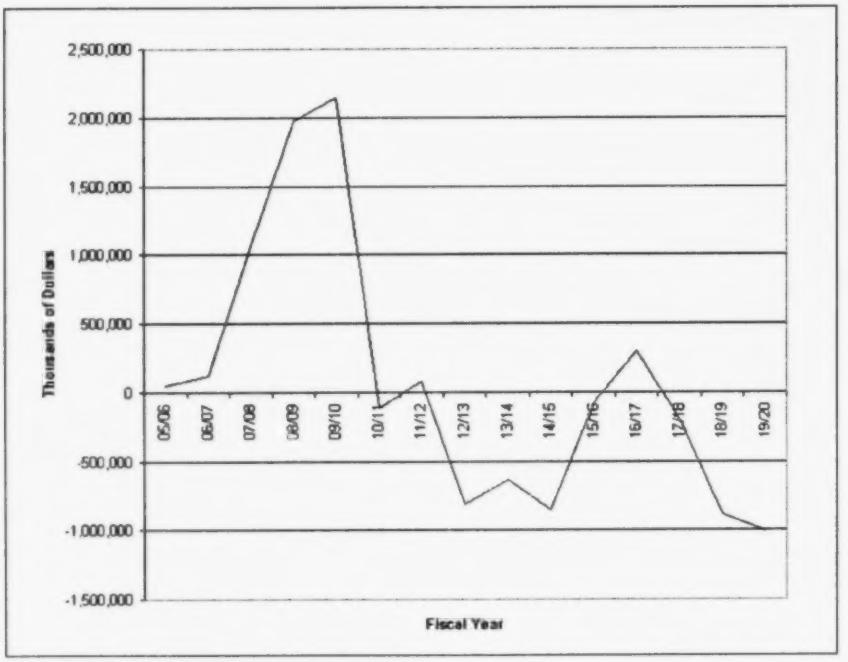


Figure 9: *The Planning Space*

The last set of output figures highlight the apportioned funding according to each capability-based equipment investment thrust. Figure 10 shows the results pre-DSA model run. Note the peak decrease in FY 09/10 as well as the decrease in the thrusts, most notably for Effective Engagement projects.

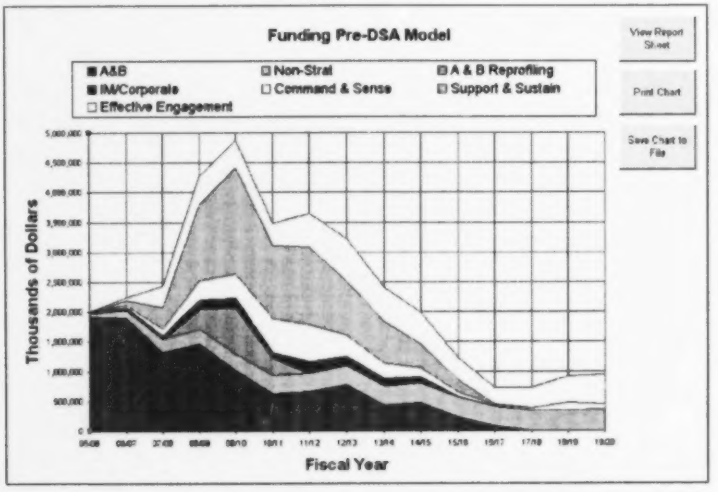


Figure 10: *Apportioned Funding – Pre-DSA Model*

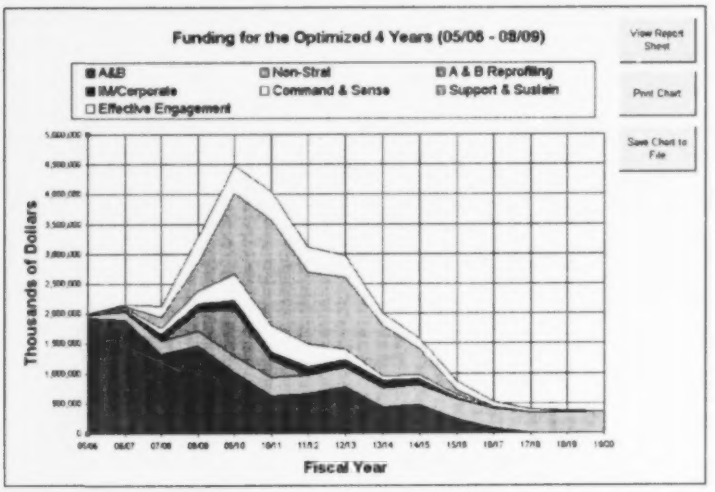


Figure 11: *Apportioned Funding – Optimized for First Four Years*

4.4 Lessons Learned from Modelling the Status Quo

Analyzing the WG's list of projects with the funding specified in the Equipment Funding Matrix (Table 3) and Project Funding Matrix (Table 4) highlight a definite lack of systematic approach to the process. Lessons learned are as follows:

- A clear and defendable ranking methodology must be established from the outset. "Clear" implies that the members know the procedure to follow and understand what they are ranking, i.e., in the scoring exercise, there were a number of blank and "???" entries. "Defendable" means that the methodology is rigorous enough to withstand careful scrutiny. Such is the case with the heuristic used in Section 2.2, with numerous documented cases of utility to the department;
- There were multiple versions of the plan put forward at various times. The initial set of 94 projects was scored, and yet later versions were not. It must be clear that ranking the projects has to be the last step before running the Slice heuristic. If it isn't and additional projects are added, the ranking must be redone;
- As a result of the poor initial Planning Space funding, the heuristic determined that 62% of the 79 projects that were funded, start within the first three years with a maximum of 43 starts in FY 07/08 alone;
- After the 43 starts in FY 07/08, there were no starts for the next 12 years (end of current SCIP timeline) as a result of the model trying to overcome the large negative funding delta in the later years. Starting a project means that its timeline is fixed to some extent, i.e., the timeline doesn't move but can "stretch out" to the right as funding shifts to make the plan affordable in any FY according to the heuristic of Section 3.3;
- Analysis has shown that shifting projects to the right can create problems in later years as a large funding demand can shift to where there was once a much smaller demand and thereby affecting the delta considerably.

5 Conclusions and Recommendations

This report documents a model that strives to bring the rigor of computer simulation, risk analysis and optimization into the SCIP process. It easily lends itself to 'What if' type analyses through varying the input funding, the likelihood of a decrease in funding, the range of a possible decrease and adjustments to project start dates. The model, once implemented, will support a more sophisticated and rigorous approach to planning and prioritizing future strategic capital (equipment) projects.

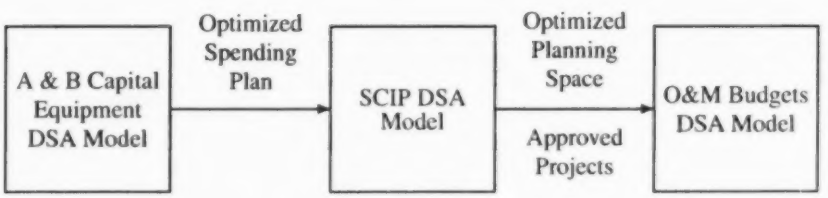
The model will evolve with time as suggestions are implemented. For example, it might be useful to protect certain projects from adjustments to start dates and/or cash phasings if their total cost is below a user specified threshold, e.g., $50M. This would mean that the brunt of adjustments would be taken by the larger projects, a not unreasonable assertion.

It has also been proposed that a similar decision support model be developed for projecting A and B capital (equipment) project spending based on historical expenditure patterns and other risk parameters as determined appropriate [3]. The output from this model would be a projected A and B spending plan that would then be input into the SCIP DSA Model to help determine the amount of free planning space available to start new projects.

A further O&M Sustainability (or affordability) decision support model was suggested to take the results of the SCIP model, which would identify the number of new projects that could be accommodated over the planning horizon, given funding and other constraints, as an input in order to determine the impact on future O&M budgets that approving and implementing the SCIP projects would have. By applying known and projected O&M funding constraints, only those projects that respected the constraints would be candidates for approval, or the model could simply help identify future O&M funding gaps that the department would have to take action to address during the subsequent project approval process.

In effect, the planning process would involve a triumvirate of distinct but related decision support models with the output from the first (A & B capital project future spending model) used as an input for the second (SCIP DSA model) and the output from the second used as an input for the third (future O&M impact decision support tool) as shown in Figure 12 below [4].

Figure 12: *The Decision Support Analysis Series of Models*



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Annex A
Prioritized Project List

Tables A.1-4 list the 94 projects as originally specified and ranked by the SCIP working group as of 27 April 05 [13]. Column 1 lists the project title as specified in the SCIP and relative to the WG ranking; column 2 identifies the capability-based equipment investment thrust under which each project lies and the link between capability planning and long-term capital spending; column 3 lists the rankings as calculated by the WG; column 4 lists the rankings of all 94 projects from the Slice heuristic relative to the WG numbering scheme. For example, Project 17 from the WG is now ranked in 21st place by Slice; column 5 lists the rankings from the Slice heuristic for the first 30 projects relative to the WG numbering scheme. For example, Project 41 from the WG is now ranked in 37th place by Slice.

Table A.1: *Project List Prioritized by Working Group and the Slice Program*

Project Title	Capability Link	Working Group Ranking	Slice all Projects Ranked	Slice Top 30 Ranked
Joint Information & Intel Fusion Center	C&S[a]	1	1	1
CF Command System II	C&S	2	2	2
Wideband Satcom Capability Improvement	IM/Corp[b]	3	3	3
Joint Support Ship (Implementation)	S&S[c]	4	4	4
Coalition Aerial Surv & Recon	C&S	5	5	5
Combat ID	S&S	6	6	6
Joint Space Support Project	C&S	7	7	7
Joint Unmanned Vehicles	C&S	8	8	8
Medium Lift Helicopter (1025M)	S&S	9	9	9
Multi-Mission Effects Vehicle	EE[d]	10	10	10
Satellite Broadcast System	IM/Corp	11	11	11
Information Management Interface (IMI ET)	IM/Corp	12	12	12
Battlefield Combat ID	EE	13	13	13
CF Command System III	C&S	14	14	14
LF ISTAR	C&S	15	15	15
Polar Epsilon	C&S	16	16	16
Red Switched Network	IM/Corp	17	18	17
Amphibious Sealift Capability	EE	18	20	18

[a]Thrust: Command & Sense
[b]Thrust: Information Management/Corporate
[c]Thrust: Support & Sustain
[d]Thrust: Effective Engagement

Table A.2: *Project List Prioritized by Working Group and the Slice Program (Cont'd)*

Project Title	Capability Link	Working Group Ranking	Slice all Projects Ranked	Slice Top 30 Ranked
National Military Support Capability (NMSC)	S&S[a]	19	21	19
Hercules Replacement/Modernization	S&S	20	22	20
Urban Ops Trg Sym (UOTS)	EE[b]	21	17	21
Satellite Surveillance	C&S[c]	22	19	22
Medium Support Vehicle System	S&S	23	23	23
Air Omnibus Tactical Data Link X	C&S	24	24	24
Gnd Based Urban Area Radar Detection Capability	C&S	25	25	25
Data Link Modernization	EE	26	26	26
Military SatCom Follow On	C&S	27	27	27
HFX Class C2 Mod (HMCCS)	EE	28	28	28
Single-Ship Transition Project	EE	29	29	29
Light Armoured Recce Vehicle	EE	30	30	30
CADS (son of R/SAOC)	C&S	31	31	32
UHF/VHF GAG Radio Replacement	IM/Corp[d]	32	32	32
NATO Air Ground Surveillance	C&S	33	33	33
Tactical Information Dist Enhance (TIDE)	C&S	34	34	34
Strategic Radios - HF (SHARP)	IM/Corp	35	35	37
NBC Command Information Ops Center	C&S	36	36	38
Light Forces Enhancements	EE	37	37	41
Data Management System Upgrade	EE	38	38	35
Coyote Life Extension	C&S	39	39	36
Frigate Life Extension	EE	40	40	42
Soldier System 2020	EE	41	41	43
Company Area Suppression Wpn	EE	42	42	45
MASIS	IM/Corp	43	43	47
Halifax Class Radar Upgrade Project	EE	44	44	48
Interconnectivity Project	EE	45	45	39
Integrated Soldier System Platform (ISSP)	EE	46	46	40

[a]Thrust: Support & Sustain
[b]Thrust: Effective Engagement
[c]Thrust: Command & Sense
[d]Thrust: Information Management/Corporate

Table A.3: *Project List Prioritized by Working Group and the Slice Program (Cont'd)*

Project Title	Capability Link	Working Group Ranking	Slice all Projects Ranked	Slice Top 30 Ranked
Mobile Gun System	EE[a]	47	47	44
ACES - (AKA LF Command & Control)	C&S[b]	48	48	46
Global Position System Phase 2	EE	49	49	50
Defensive Electronic Warfare Suite	EE	50	50	55
Force Mobility Enhancement	S&S[c]	51	51	56
Vital Point Bio Agent Detection	EE	52	52	64
NBC Recce System (Previously "Vehicle")	EE	53	53	49
Chemical Agent Detect/Sample/ID	EE	54	54	51
Electro-Optical System Upgrade	EE	55	55	52
New Fighter Capability	EE	56	56	53
Area Surv/Secondary Surv Radar (ASR/SSR)	S&S	57	57	54
AIMP Stand off Weapon	EE	58	58	60
CF-18 Advanced Precision Guided Munition	EE	59	59	76
Biological Warfare Threat Counter-measure Project	S&S	60	60	93
Surveillance of Space	C&S	61	61	58
Submarine Life Extension	EE	62	62	59
Future Indirect Fire Capability	EE	63	63	66
Acoustic System Modernization	EE	64	64	71
Joint Strike Fighter Development	EE	65	65	57
Small Arms Replacement Project II	EE	66	66	61
Underwater Defence Project	EE	67	67	73
Light Vehicle Wheeled	S&S	68	68	77
CFUTTH Mid-Life Upgrade	EE	69	69	80
CF-18 Defensive Electronic Warfare Suite	EE	70	70	82
Advanced Lightweight Anti-Armour Weapon System	EE	71	71	62
Griffon ERSTA	EE	72	72	65
MCDV - 3 remaining items	EE	73	73	84
MCDV Life Extension	EE	74	74	74

[a]Thrust: Effective Engagement
[b]Thrust: Command & Sense
[c]Thrust: Support & Sustain

Table A.4: *Project List Prioritized by Working Group and the Slice Program (Cont'd)*

Project Title	Capability Link	Working Group Ranking	Slice all Projects Ranked	Slice Top 30 Ranked
CTS - NBC Overboot	S&S[a]	75	75	70
CEMS - 2 MRs (Safety Goggles & Air Ops Glove)	S&S	76	76	68
Clothe the Soldier ReScope	S&S	77	77	63
Pers Anti Armour Wpn (M72 replacement)	EE[b]	78	78	67
CEMS - Brassiere Temperate Underwear	S&S	79	79	75
CEMS Tactile Cold Weather Gloves	S&S	80	80	79
CEMS - Fleece Suit	S&S	81	81	81
Combat Veh Crew Helmet	S&S	82	82	83
Naval Improved Clothing & Eqmt	S&S	83	83	85
Utility Aircraft (152M)	C&S[c]	84	84	86
CEMS - 5 MRs (T-Shirt, Laces, knee pads)	S&S	85	85	87
CEMS Thermal Underwear	S&S	86	86	88
CEMS Extreme Cold Weather Boots	S&S	87	87	90
CEMS Sunglasses	S&S	88	88	78
MK 46 Torpedo Replace	EE	89	89	69
CEMS Multitool	S&S	90	90	72
CIMP	IM/Corp[d]	91	91	89
MK 48 Torpedo Refurbish	EE	92	92	91
TXXR to Small L1 Non-Strategic program	S&S	93	93	92
Snowbird Aircraft Replacement Project	IM/Corp	94	94	94

[a]Thrust: Support & Sustain
[b]Thrust: Effective Engagement
[c]Thrust: Command & Sense
[d]Thrust: Information Management/Corporate

Annex B
Running the SCIP DSA Model

B.1 Installation

Installation of the SCIP DSA model is straightforward. The zipped application just needs to be copied to a folder on the user's hard drive and unzipped (Figure B.1). [15] Double-clicking on the expanded file "SCIP DSA Model.xls" will launch the model. The SCIP DSA model is run by coded Visual Basic for Applications (VBA) subroutines and macros; when prompted by Excel, the user must press the "Enable Macros" button for full functionality.

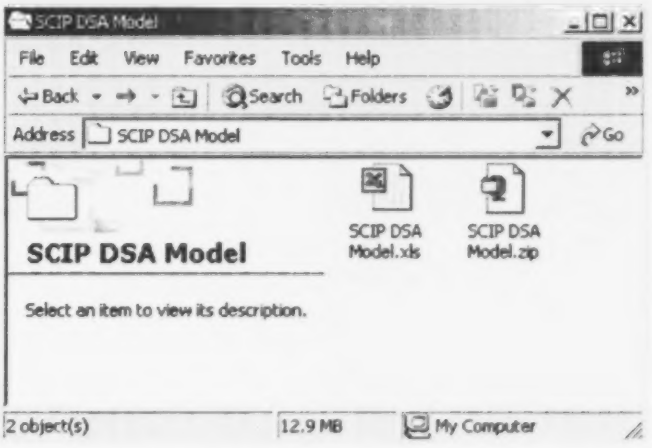


Figure B.1: *The SCIP Decision Support Analysis Model*

B.2 The Risk Analysis Software

At this stage, unless the user has previously installed the risk analysis software, *@Risk* [15], the model will fail at the compile stage. At least the standard version of this software must be installed before continuing. The *@Risk* software is crucial for providing the random sampling for the probability distribution functions contained in the VB code and for recalculating the Excel worksheet using the new values. Normally, the risk analysis software is used to generate statistical distributions of all possible results; however, since we are more concerned we deriving the particular cash phasing that minimizes the delta, simulation results that include distributions of output values is not required. However, a later version is expected to include sensitivity analysis to identify those input distributions most critical to the results.

[15] The ultimate size of the application is dependent on the number of iterations. Since the heuristic extracts results for the cash phasing of each project per iteration, a SCIP consisting of 94 projects with a phasing of 16 FYs each and 1000 iterations would create a file in excess of 70MB.

B.3 Starting the Model

B.3.1 The SplashScreen

Double-clicking on the application icon will bring up the splash screen shown in Figure B.2. A Splash screen is an image that appears while a program or operating system is loading. Most large applications use splash screens to provide feedback to the user, and as advertising information of version and developer. This screen will disappear after a few seconds.

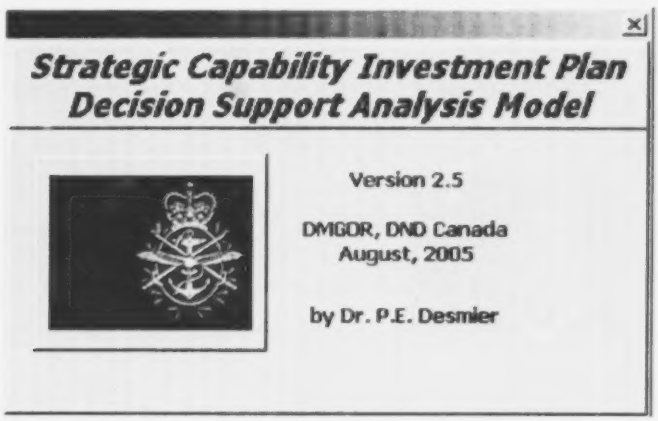


Figure B.2: *The SCIP DSA Model SplashScreen*

B.3.2 Main Menu

The screen that follows the splash screen contains the main menu (Figure B.3). This is the starting point for running the simulation. There are five important features on this sheet: Four buttons: 'Run SCIP DSA Model', 'SCIP DSA Model Explained', 'Exit' and 'Edit', and a cell for entering the number of iterations for the Monte Carlo simulation.

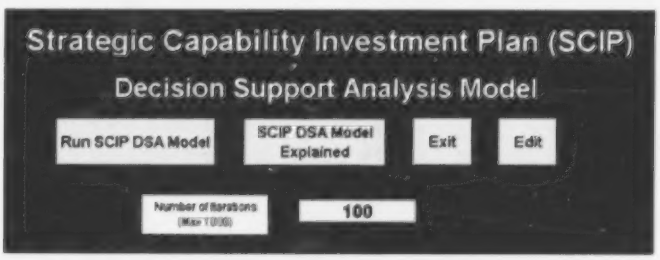


Figure B.3: *The Main Menu Screen*

Clicking the button 'Run SCIP DSA Model' starts the Monte Carlo simulation using simulation settings of Latin Hypercube sampling with a random number generator seed chosen

randomly. The heuristic runs, outputs are stored within the *@Risk* software and after each iteration the 'Master' worksheet refreshes itself with the original cash phasings.

Execution of the simulation is indicated by the window shown in Figure B.4, where, for example, 350 iterations (35%) of a total of 1000 iterations have already been completed. The simulation may be halted at any time by clicking the 'Cancel' button. Output results are then displayed for the iterations that have finished, however, convergence of the displayed output distributions may not have been achieved unless enough iterations have run.

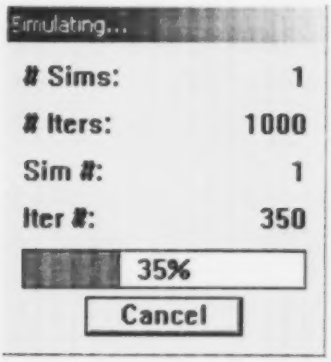


Figure B.4: @Risk *Simulating*

Clicking the 'SCIP DSA Model Explained' opens a form that provides a brief description of the heuristic. Clicking the 'Exit' button automatically prompts the user to save any changes made to the SCIP DSA Model. The model will then close. The 'Edit' button is necessary if any changes are required to the model. One of the actions that automatically takes place upon opening the application is the hiding of all data worksheets so that the interface is "clean". Clicking the 'Edit' button unhides all worksheets.

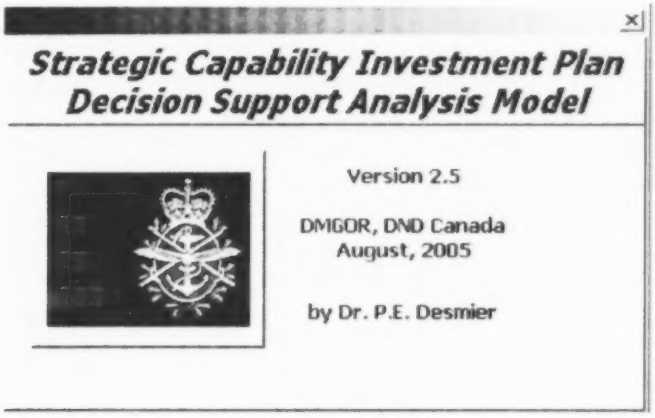
The 'Number of Iterations' is an input requirement of *@Risk*. Any positive integer between 1 and 1000 can be entered, however, too small a number and the results may not be consistent with subsequent runs. At 1000 iterations, it is reasonable to expect convergence in the output variables. A run of only 100 iterations, as displayed in Figure B.3, is good enough for diagnostics and model testing.

A user must enter a value into the 'Number of Iterations' cell and tab-out for the application to accept the entry.

B.3 Starting the Model

B.3.1 The SplashScreen

Double-clicking on the application icon will bring up the splash screen shown in Figure B.2. A Splash screen is an image that appears while a program or operating system is loading. Most large applications use splash screens to provide feedback to the user, and as advertising information of version and developer. This screen will disappear after a few seconds.



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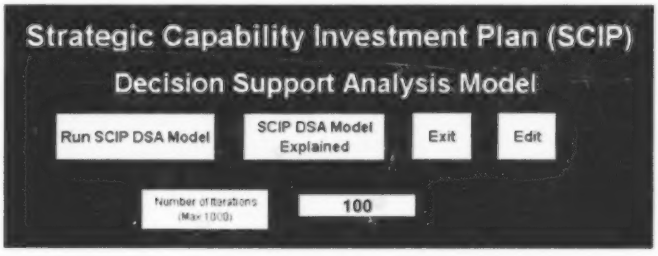

Figure B.3: *The Main Menu Screen*

Clicking the button 'Run SCIP DSA Model' starts the Monte Carlo simulation using simulation settings of Latin Hypercube sampling with a random number generator seed chosen

randomly. The heuristic runs, outputs are stored within the *@Risk* software and after each iteration the 'Master' worksheet refreshes itself with the original cash phasings.

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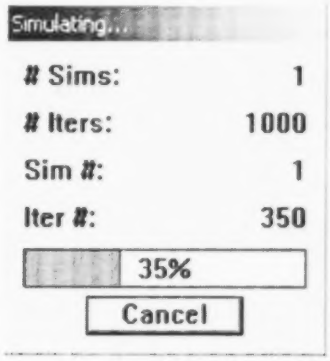


Figure B.4: @Risk *Simulating*

Clicking the 'SCIP DSA Model Explained' opens a form that provides a brief description of the heuristic. Clicking the 'Exit' button automatically prompts the user to save any changes made to the SCIP DSA Model. The model will then close. The 'Edit' button is necessary if any changes are required to the model. One of the actions that automatically takes place upon opening the application is the hiding of all data worksheets so that the interface is "clean". Clicking the 'Edit' button unhides all worksheets.

The 'Number of Iterations' is an input requirement of *@Risk*. Any positive integer between 1 and 1000 can be entered, however, too small a number and the results may not be consistent with subsequent runs. At 1000 iterations, it is reasonable to expect convergence in the output variables. A run of only 100 iterations, as displayed in Figure B.3, is good enough for diagnostics and model testing.

A user must enter a value into the 'Number of Iterations' cell and tab-out for the application to accept the entry.

B.4 Input Data Options

Clicking the button 'Run SCIP DSA Model' causes the message shown in Figure B.5 to be displayed. The SCIP DSA Model is the only Excel application that can be open. Clicking 'Yes' will halt the simulation and return the user to the Windows environment to close all other Excel applications. Clicking 'No' will continue the simulation where the *Risk Ranges* form shown in Figure B.6 is displayed.

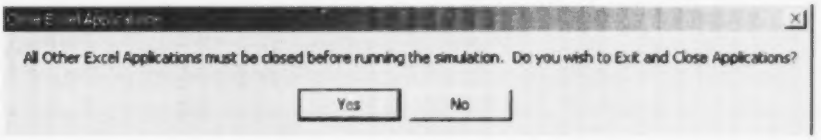

All Other Excel Applications must be closed before running the simulation. Do you wish to Exit and Close Applications?
Yes
No

Figure B.5: *Close Excel Applications*

B.4.1 The Risk Ranges Form

The *Risk Ranges* form (Figure B.6) describes the probabilities for the heuristic (item 2, Section 3.3. The first line inputs the probabilities of not getting 100% funding in the specified project year. These values, input as decimals, describe the likelihood that a project's funding in a particular year will be less then the initial demand. For example, in Year 1, the default value of 1.0 indicates that there is a certainty that the funding in the first year of a project's life will be less then the demand. Over time, the likelihood of a cut in funding decreases, and stays constant at 25% for all years greater then 3.

If the random number chosen is less then the specified probability, a decrease in funding is expected, with the amount of decrease specified by sampling the triangular distribution with 'Minimum', 'Most Likely' and 'Maximum' values shown on the form. The default minimum and most likely values describe a right-angle distribution as a consequence of a purely estimated apportioning of funds to a project over time [16].

After either accepting the defaults or making changes to the cells, the user must click the 'OK' button for the simulation to continue. The cells on the form are then copied to the applicable Excel worksheet for further processing by the model. Clicking the 'Abort Run' button immediately terminates the run with any changes ignored.

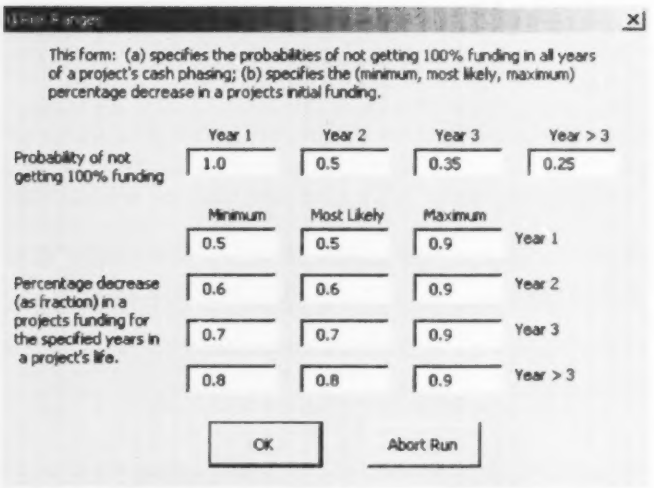
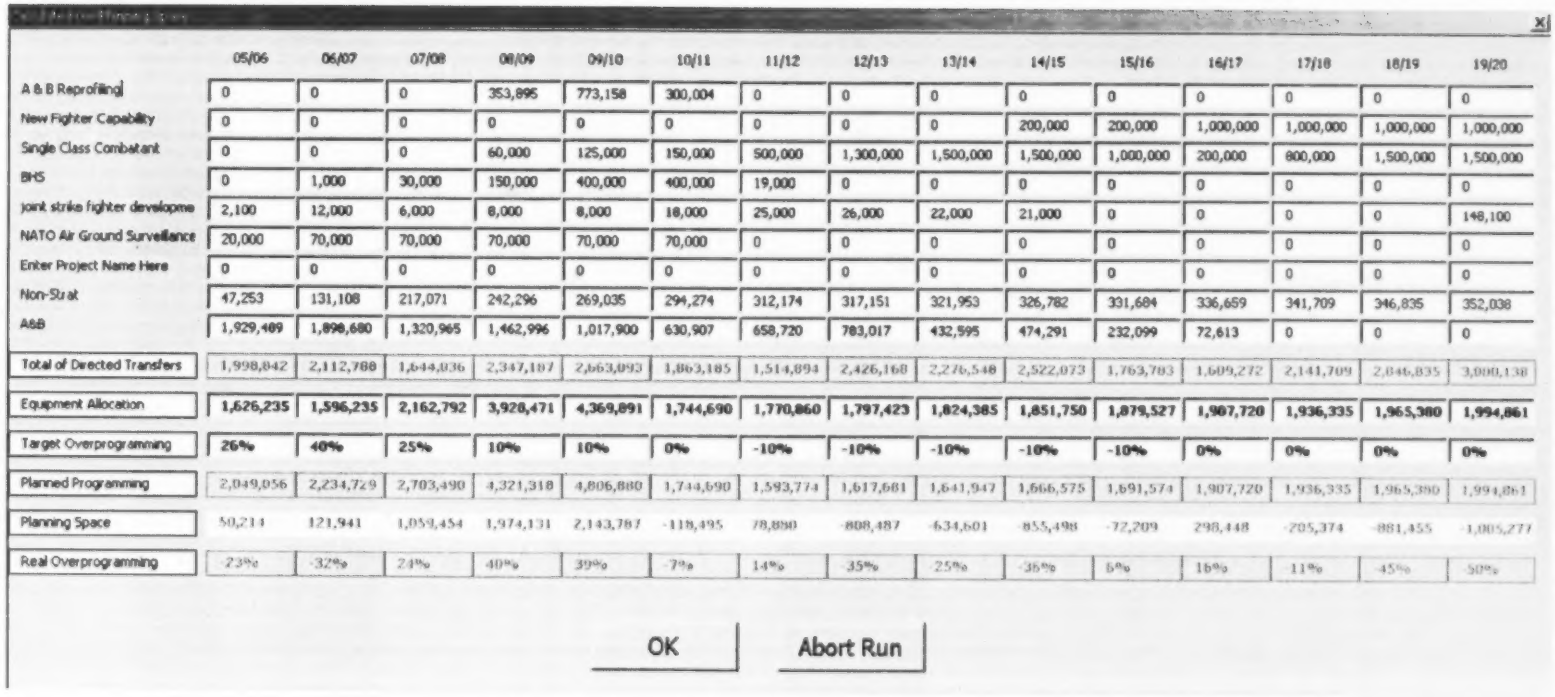


Figure B.6: *Input Form to Specify Ranges to* @Risk *Probability Distributions*

B.4.2 Planning Space Form

The *Planning Space* form (Figure B.7) describes the EFM found in Table 3. The user has the option to change any cell in the first nine rows (including the project/funding name); all cells in the Equipment Allocation row; and, all cells in the Target Overprogramming row. All other cells are calculated based on equations (3) – (5). Values can be entered unformatted as the model automatically formats numbers correctly.

Clicking the 'OK' button continues the simulation. All cells on the form are then copied to the applicable Excel worksheet for further processing by the model. Clicking the 'Abort Run' button immediately terminates the run with any changes ignored.



	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20
A & B Reprofiling	0	0	0	353,896	773,158	300,004	0	0	0	0	0	0	0	0	0
New Fighter Capability	0	0	0	0	0	0	0	0	0	200,000	200,000	1,000,000	1,000,000	1,000,000	1,000,000
Single Class Combatant	0	0	0	60,000	125,000	150,000	500,000	1,300,000	1,500,000	1,500,000	1,000,000	200,000	800,000	1,500,000	1,500,000
BHS	0	1,000	30,000	150,000	400,000	400,000	19,000	0	0	0	0	0	0	0	0
joint strike fighter developme	2,100	12,000	6,000	8,000	8,000	18,000	25,000	26,000	22,000	21,000	0	0	0	0	148,100
NATO Air Ground Surveillance	20,000	70,000	70,000	70,000	70,000	70,000	0	0	0	0	0	0	0	0	0
Enter Project Name Here	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Non-Strat	47,253	131,108	217,071	242,296	269,035	294,274	312,174	317,151	321,953	326,782	331,684	336,659	341,709	346,835	352,038
A&B	1,929,489	1,898,680	1,320,965	1,462,996	1,017,900	630,907	658,720	783,017	432,595	474,291	232,099	72,613	0	0	0
Total of Directed Transfers	1,998,842	2,112,788	1,644,036	2,347,187	2,663,093	1,863,185	1,514,894	2,426,168	2,276,548	2,522,073	1,763,783	1,609,272	2,141,709	2,846,835	3,000,138
Equipment Allocation	**1,626,235**	**1,596,235**	**2,162,792**	**3,928,471**	**4,369,891**	**1,744,690**	**1,770,860**	**1,797,423**	**1,824,385**	**1,851,750**	**1,879,527**	**1,907,720**	**1,936,335**	**1,965,380**	**1,994,861**
Target Overprogramming	**26%**	**40%**	**25%**	**10%**	**10%**	**0%**	**-10%**	**-10%**	**-10%**	**-10%**	**-10%**	**0%**	**0%**	**0%**	**0%**
Planned Programming	2,049,056	2,234,729	2,703,490	4,321,318	4,806,880	1,744,690	1,593,774	1,617,681	1,641,947	1,666,575	1,691,574	1,907,720	1,936,335	1,965,380	1,994,861
Planning Space	50,214	121,941	1,059,454	1,974,131	2,143,787	-118,495	78,880	-808,487	-634,601	-855,498	-72,209	298,448	-205,374	-881,455	-1,005,277
Real Overprogramming	-23%	-32%	24%	40%	39%	-7%	14%	-35%	-25%	-36%	6%	16%	-11%	-45%	-50%

OK | Abort Run

Figure B.7: *Input Form to Calculate Free Planning Space*

B.4.3 Adjust Start Date Form

The *Adjust Start Date* form allows the user to move a project's entire cash phasing to the right or left from its initial position prior to running the model. It does this by shifting the funds in the worksheet according to a new 'Start FY'.

Figure B.8 shows the form containing the entire project list, which is loaded at start-up from the master Excel worksheet. There are two columns of information that are loaded: A Defence Services Program (DSP) number which labels the project as belonging to a particular Level 1; and, the project title. The user then has two choices for finding a project in the list, (a) they can either enter the first few characters of the DSP number, or (b) enter the first few characters of the project title. In either case, the algorithm starts selecting projects with the first character entered and only stops when the search retrieves an unambiguous record. In the example shown, adding the character 'r' removed any ambiguity as there are three projects that started with the characters 'da', i.e., 'Data Link Modernization', 'Data Management System Upgrade' and 'DART Upgrades' (case is ignored). If characters are entered that don't match any in the list, a message is displayed on the form stating 'Project is not in list', at which point the user can either correct the text or select a project from the list by using the scroll bar on the right or arrow keys on the keyboard.

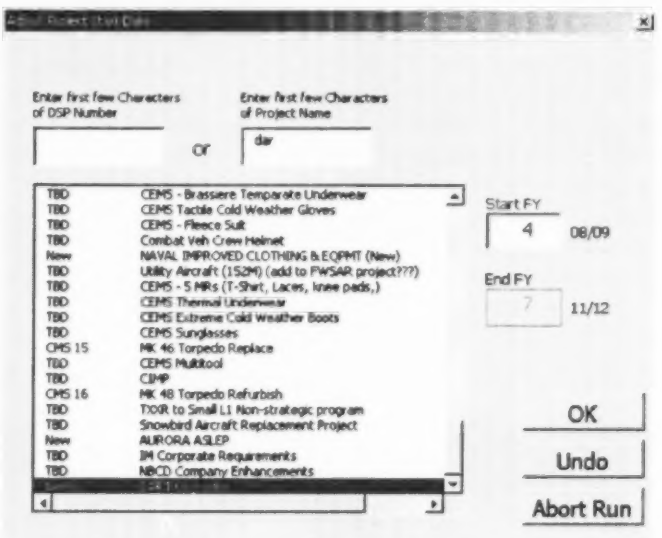

Enter first few Characters of DSP Number
or
Enter first few Characters of Project Name
dar
TBD CEMS - Brassiere Temperate Underwear
TBD CEMS Tactile Cold Weather Gloves
TBD CEMS - Fleece Suit
TBD Combat Veh Crew Helmet
New NAVAL IMPROVED CLOTHING & EQPMT (New)
TBD Utility Aircraft (152M) (add to FWSAR project???)
TBD CEMS - 5 MRs (T-Shirt, Laces, knee pads,)
TBD CEMS Thermal Underwear
TBD CEMS Extreme Cold Weather Boots
TBD CEMS Sunglasses
CMS 15 MK 46 Torpedo Replace
TBD CEMS Multitool
TBD CIMP
CMS 16 MK 48 Torpedo Refurbish
TBD TDDR to Small L1 Non-strategic program
TBD Snowbird Aircraft Replacement Project
New AURORA ASLEP
TBD IM Corporate Requirements
TBD NBCD Company Enhancements
Start FY
4
08/09
End FY
7
11/12
OK
Undo
Abort Run

Figure B.8: *Input Form to Adjust Individual Project Start Dates*

Once a project is selected, the 'Start FY' holds the initial start date and 'End FY' holds the initial completion data for the project with FY's $[1, 2, 3, \ldots 15, 16]$ equating to FY's $[05/06, 06/07, 07/08, \ldots 19/20, \mathit{Future}]$ respectively. If the project is not funded, both the 'Start FY' and 'End FY' boxes will have zeros entered and the message 'Project is not funded' is displayed. If the project is funded, the user can adjust the start date by entering a number in the 'Start FY' box. If the end date extends beyond the SCIP timeline, all costs

beyond FY 19/20 are summed into the *Future* cell, i.e., in the example shown, the project 'DART Upgrades' starts in FY 08/09 and has a duration of four years. Therefore, entering a value of 14 in the 'Start FY' box will mean that cells 'Future' and 'Future+1' would be summed into the 'Future' cell.

Once the user tabs out of the 'Start FY' box, the changes are accepted by the model and only by clicking the 'Undo' button could the changes be reversed. Clicking the 'OK' button would exit the form and finalize any changes. Clicking the 'Abort Run' button would also reverse any changes prior to terminating the run.

B.5 Error Checking

Throughout the user entry portions of the model, errors in the data entry are automatically flagged for the user to take corrective action.

B.5.1 Main Menu Error Checking

Such is the case with the 'Number of Iterations' on the 'Main Menu' sheet (Figure B.3). The user must enter a value in the cell and tab-out of the cell for the application to accept the entry. If zero, a negative value or a value greater than 1000 is entered, a message as shown in Figure B.9 is displayed and the user is returned to the worksheet to correct the entry.

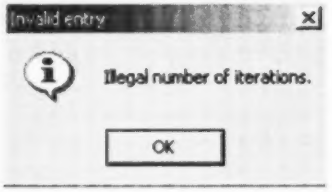


Figure B.9: *Message for Invalid Entry in 'Number of Iterations' Cell*

B.5.2 Risk Ranges Form Error Checking

All entries in the 'Risk Ranges' form are probability values that are critical to the successful running of the heuristic. Invalid entries occur when the user either enters a non-numeric or negative character, a probability greater than one or specifies an invalid range for the triangular distribution.

When a value is entered, the model first checks to make sure it is numeric. If it is non-numeric, the message in Figure B.10 is displayed and the user is returned to the textbox in question for correction. Until a numeric value is entered, the model will not relinquish control to the user. Similarly, if a non-negative probability is entered, the message in Figure B.11 is displayed and the user is returned to the textbox in question for correction. Until a positive value is entered, the model will not relinquish control to the user.

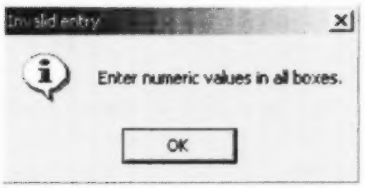


Figure B.10: *Message for Non Numeric Entry*

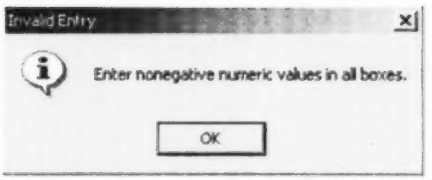


Figure B.11: *Message for Non Negative Entry*

The model also checks for "correctness" in probabilities. If a probability greater then 1.0 is entered, the message in Figure B.12 is displayed and the user is returned to the textbox in question for correction. Until a value less then one is entered, the model will not relinquish control to the user. Also, for the three values required to define the range of the triangular distribution, if the range: [Minimum $\leq$ Most Likely $\leq$ Maximum] is violated, the message in Figure B.13 is displayed and the user is returned to the textbox in question for correction.

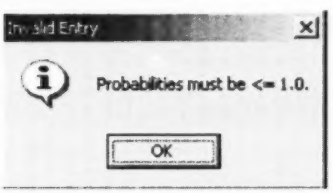


Figure B.12: *Message for Probability Limit Error*

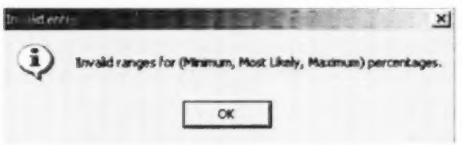


Figure B.13: *Message for Bad Range for Triangular Distribution*

B.5.3 Planning Space Form Error Checking

The Planning Space form requires a variety of number formats that are automatically adjusted to suit the particular format of the cell. Entering a number in the percentage cell will automatically reformat the number as a percentage. Similarly, a blank entry is replaced by a '0' and any number greater than 999 is automatically formatted with a ',' as the 1000 separator.

B.5.4 Adjust Start Date Form Error Checking

The Adjust Start Date form takes its input directly from the master Excel worksheet that lists the prioritized SCIP projects. If a user enter a DSP Number or Project Title that is not in the list, a message stating 'Project is Not in List' is displayed in red directly on the form. The user can then either correct the mistake or manually select a project from the list.

When entering the 'Start FY' number, there are two tests that the entry undergoes:

- If a non-numeric character is entered, a message as in Figure B.10 is displayed and control is returned to the user for correction;

- If a negative number is entered, a message as in Figure B.11 is displayed and control is returned to the user for correction.

B.5.5 @Risk Error Checking

The VBA code developed for the SCIP DSA Model uses public @Risk variables and functions to facilitate the simulation. The function 'RiskSetSettings', for example, is used to set the simulation to the current @Risk settings. The return value of the function is zero if the call is successful. If the return value is non-zero, an error has occurred and the value is passed to the 'RiskError' function to get a description and location of the error. Figure B.14 is an example of an error generated through the 'RiskSetSettings' function. Clicking the 'OK' button aborts the simulation.

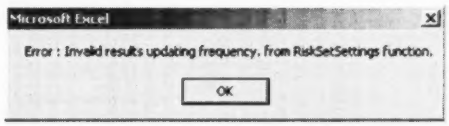


Figure B.14: *Error Generated at RiskSetSettings*

Other @Risk error checking occurs within the functions 'RiskGetSettings', 'RiskGenerateReports' and 'RiskSimulate'.

B.5.6 Office 2000 Error Checking

The SCIP DSA Model is designed to work with Excel 2000 or later. Should the user try to run the application from an earlier version, the message displayed in Figure B.15 is shown and the workbook is closed.

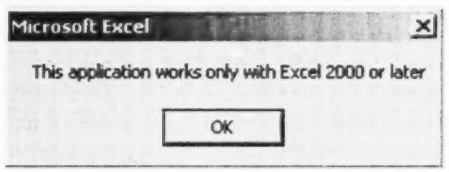


Figure B.15: *Office 2000 Check*

List of symbols/abbreviations/acronyms/initialisms

ADM(HR Mil)	Assistant Deputy Minister(Human Resources–Military)
ADM(IM)	Assistant Deputy Minister(Information Management)
ADM(Pol)	Assistant Deputy Minister(Policy)
ADM(S&T)	Assistant Deputy Minister(Science and Technology)
CF	Canadian Forces
CAS	Chief of the Air Staff
CDS	Chief of the Defence Staff
CLS	Chief of the Land Staff
CMS	Chief of the Maritime Staff
DCDS	Deputy Chief of the Defence Staff
DFPPC	Director Force Planning and Program Coordination
DM	Deputy Minister
DND	Department of National Defence
DRDC	Defence Research and Development Canada
DSA	Decision Support Analysis
DSP	Defence Services Program
EFM	Equipment Funding Matrix
FY	Fiscal Year
IM	Information Management
IT	Information Technology
JCRB	Joint Capability Requirement Board
MARCUS	Multi-Criteria Analysis and Ranking Consensus Unified Solution
O&M	Operations and Maintenance
PFM	Project Funding Matrix
PMB	Program Management Board
SCIP	Strategic Capability Investment Plan
Tri	Triangular
VBA	Visual Basic for Applications
WG	Working Group

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Updating the SCIP equipment annex for C Status and below projects is an annual process that consumes a great deal of staff time and resources. This report documents a model that strives to bring the rigor of computer simulation, risk analysis and optimization into the SCIP process. It easily lends itself to 'What if' type analyses through varying the input funding, the likelihood of a decrease in funding, the range of a possible decrease and adjustments to project start dates.

The model, once implemented, will support a more sophisticated and rigorous approach to planning and prioritizing future strategic capital (equipment) projects and, it is foreseen, form the nucleus of three distinct but related decision support analysis models where the output from an A and B capital equipment future spending model is used as input to the SCIP decision support model described herein. Its output in turn would be used as an input to a third, future O&M decision support model to determine the impact on future O&M budgets from approving and implementing the SCIP projects.

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Capability
Investment
Capital
O&M
Equipment
Overprogramming
Underprogramming
Monte Carlo
Simulation
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MARCUS
Slice
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